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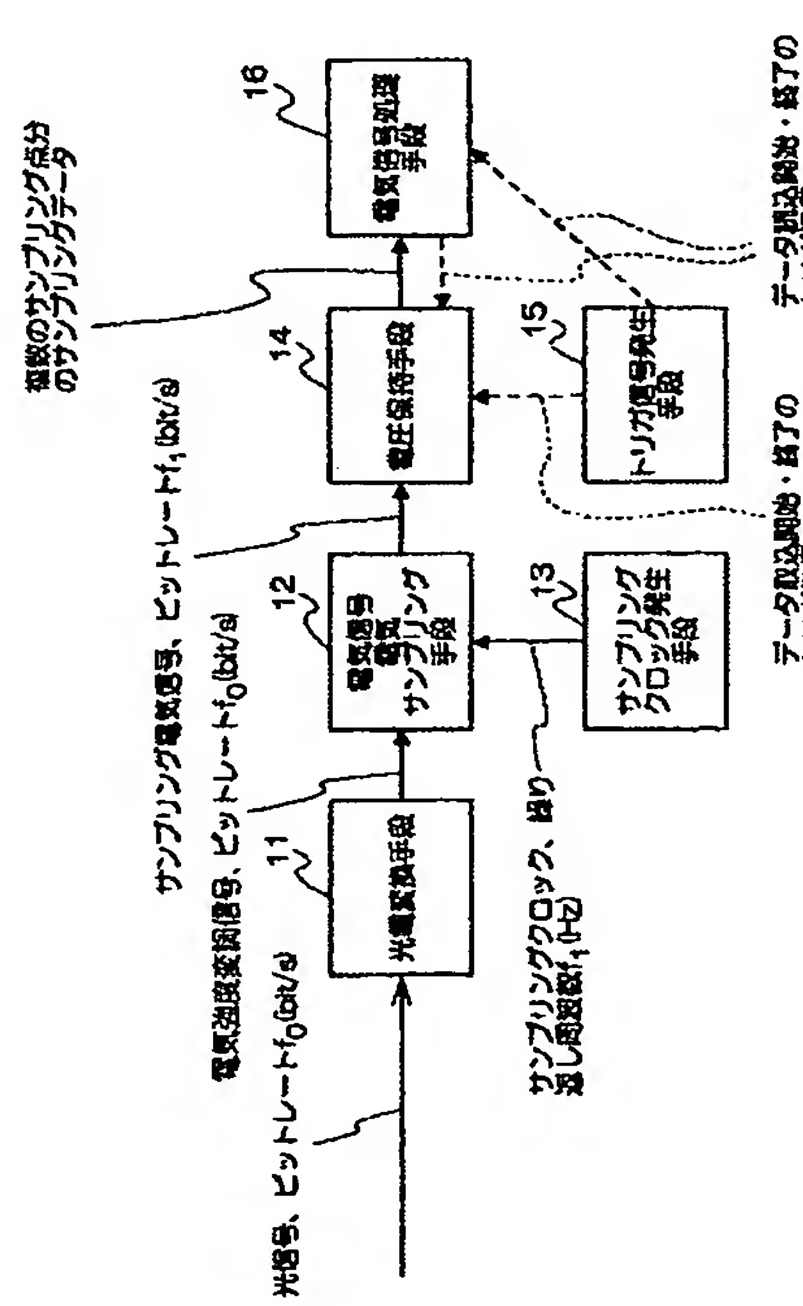
(54)【発明の名称】高速サンプリングによるデータ信号品質評価方法および装置

(57)【要約】
【課題】クロック抽出部を不要とすることで装置規模の小型化・簡易化を図る。
【解決手段】入力されるビットレートｆ₀（ｂｉｔ／ｓ）の光または電気のデータ信号とは独立に生成されるものであって、ビットレートｆ₀（ｂｉｔ／ｓ）とは異なる繰り返し周波数ｆ₁（Ｈｚ）の光または電気のサンプリングパルス列を発生するサンプリングパルス列発生手段と、ビットレートｆ₀（ｂｉｔ／ｓ）の該データ信号を該サンプリングパルス列でサンプリングしサンプリング信号を得るデータ信号サンプリング手段と、該データ信号サンプリング手段によって得られる光または電気の該サンプリング信号を変換し、電気のデジタルデータとして複数データ分記憶する電圧保持手段と、該電圧保持手段に保持されているデジタルデータを一度にまたは順次読み込んで信号アイパタンを求め光データ信号品質パラメータを評価する電気信号処理手段と、該電圧保持手段に対してデータ取込開始と終了のトリガを与え、該電気信号処理手段にデータ



【特許請求の範囲】
【請求項１】
入力されるビットレートf_0（ｂｉｔ／ｓ）の光または電気のデータ信号とは独立に生成されるものであって、ビットレートf_0（ｂｉｔ／ｓ）とは異なる繰り返し周波数f_1（Ｈｚ）の光または電気のサンプリングパルス列を用いて、該データ信号をサンプリングし、得られる光または電気のサンプリング信号を変換して電気のデジタルデータとしてバッファに保持する工程をＮ回（Ｎは自然数）繰り返した後に、
前記バッファに保持されているＮ個のデジタルデータを一度にまたは順次読み出して電気信号処理を行うことにより、信号アイパタンを求めデータ信号波形測定および品質評価を行うことを特徴とするデータ信号品質評価方法。
【請求項２】
請求項１に記載のデータ信号品質評価方法において、前記サンプリングの繰り返し周波数f_1（Ｈｚ）が、$f_1 = (n/m) f_0 \pm a$（ｎ，ｍは自然数）を満たし、変数ａの範囲が、
【数１】

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k,\ q\text{は自然数})$$

である
ことを特徴とするデータ信号品質評価方法。
【請求項３】
請求項２に記載のデータ信号品質評価方法において、ビットレートf_0（ｂｉｔ／ｓ）の正確な値が不明である場合に、前記サンプリングの繰り返し周波数f_1（Ｈｚ）が$f_1 = (n/m) f_0 \pm a$（ｎ，ｍは自然数）かつ$(n/m)^2 q / \{k + (n/m) q\} f_0 \leqq a < (n/m)^2 q / \{k + (n/m) q - 1\} f_0$（ｋは自然数）を満たすように、$f_1$の値を掃引する
ことを特徴とするデータ信号品質評価方法。
【請求項４】
請求項２又は３に記載のデータ信号品質評価方法において、前記変数ａの値が、
【数２】

$$a = \frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

であり、サンプリングデータを測定順に時間軸方向に
$dt = 1/(z f_0)$
の時間間隔で表示するときに、最初のサンプリングデータから数えてｉｋ個（ｉは自然数）ごとに時間位置を重ね合わせてサンプリングデータを表示することにより信号アイパタンを求めてデータ信号波形測定および品質評価をおこない、かつ、
重ね合わせ回数をｊ（ｊは自然数）としたときに、全サンプリングデータ数Ｎｓａｍｐに対して、ｉｋｊ≦Ｎｓａｍｐを満たす
ことを特徴とするデータ信号品質評価方法。

【請求項５】
請求項４に記載のデータ信号品質評価方法において、前記変数ｉ，ｋが、ｉｋｊ≦Ｎｓａｍｐを満たし、かつ、
【数３】

$$ijk \leqq \frac{kz}{2q(k-z)}$$

を満たす値であることを特徴とするデータ信号品質評価方法。
【請求項６】
請求項５に記載のデータ信号品質評価方法において、ビットレートf_0（ｂｉｔ／ｓ）の正確な値が不明である場合に、前記サンプリングの繰り返し周波数f_1（Ｈｚ）がf_1＝（ｎ／ｍ）f_0±ａ（ｎ，ｍは自然数）かつ（ｎ／ｍ）^{2}ｑ／｛ｋ＋（ｎ／ｍ）ｑ｝f_0≦ａ＜（ｎ／ｍ）^{2}ｑ／｛ｋ＋（ｎ／ｍ）ｑ－１｝f_0（ｋは自然数）を満たし、かつ、ｉｋｊ≦Ｎｓａｍｐかつｉｋｊ≦ｋｚ／｛２ｑ（ｋ－ｚ）｝（ｉ，ｊ，Ｎｓａｍｐは自然数）を満たすように、ｋの値、ｎ／ｍの値、ｑの値、のいずれか一つ以上を掃引する
ことを特徴とするデータ信号品質評価方法。
【請求項７】
請求項２又は３に記載のデータ信号品質評価方法において、前記変数ａの値が、
【数４】

$$a = \frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

であり、サンプリングデータを測定順に時間軸方向に
ｄｔ＝１／（ｚf_0）
の時間間隔で表示するときに、最初のサンプリングデータの時間位置をｔ＝０としてｔ＝ｐ／f_0（ｐは自然数）ごとに時間位置を０に戻して重ね合わせてサンプリングデータを表示することにより信号アイパタンを求めてデータ信号波形測定および品質評価をおこない、かつ、
重ね合わせ回数をｊ（ｊは自然数）としたときに、全サンプリングデータ数Ｎｓａｍｐに対して、ｐｋｊ≦Ｎｓａｍｐを満たす
ことを特徴とするデータ信号品質評価方法。
【請求項８】
請求項４、５、６、又は７のいずれか１項に記載のデータ信号品質評価方法において、前記バッファに保持されている該Ｎｓａｍｐ個のサンプリングデータを一度にまたは順次読み出して電気信号処理を行って信号アイパタンを求める工程を複数回繰り返し、それぞれの信号アイパタンのアイ開口が時間的に一致するように重ね合わせることで、信号アイパタンを構成する全サンプリングデータ数を増やし、データ信号波形測定および品質評価をおこなう
ことを特徴とするデータ信号品質評価方法。
【請求項９】
請求項２、３、４，５、６、７，又は８のいずれか１項に記載のデータ信号品質評価方法において、得られる信号アイパタンを強度方向又は時間方向に分割して得られるサンプリングデータ分布から求められる振幅ヒストグラム又は時間ヒストグラムをデータ信号品質パラメータとすることを特徴とするデータ信号品質評価方法。

【請求項１０】
入力されるビットレートf_0（ｂｉｔ／ｓ）の光または電気のデータ信号とは独立に生成されるものであって、ビットレートf_0（ｂｉｔ／ｓ）とは異なる繰り返し周波数f_1（Ｈｚ）の光または電気のサンプリングパルス列を発生するサンプリングパルス列発生手段と、
ビットレートf_0（ｂｉｔ／ｓ）の該データ信号を該サンプリングパルス列でサンプリングしサンプリング信号を得るデータ信号サンプリング手段と、
該データ信号サンプリング手段によって得られる光または電気の該サンプリング信号を変換し、電気のデジタルデータとして複数データ分記憶する電圧保持手段と、
該電圧保持手段に保持されているデジタルデータを一度にまたは順次読み込んで信号アイパタンを求め光データ信号品質パラメータを評価する電気信号処理手段と、
該電圧保持手段に対してデータ取込開始と終了のトリガを与え、該電気信号処理手段にデータ読込開始・終了のトリガを与えるトリガ信号発生手段と
を備えることを特徴とするデータ信号品質評価装置。
【請求項１１】
請求項１０に記載のデータ信号品質評価装置において、
前記サンプリングの繰り返し周波数f_1（Ｈｚ）が、f_1＝（ｎ／ｍ）f_0±ａ（ｎ，ｍは自然数）を満たし、変数ａの範囲が、
【数５】

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k, q\text{は自然数})$$

である
ことを特徴とするデータ信号品質評価装置。
【請求項１２】
請求項１１に記載のデータ信号品質評価装置において、該サンプリングパルス列発生手段が、発生させるサンプリングパルス列の繰り返し周波数f_1（Ｈｚ）を可変にする機能を有し、ビットレートf_0（ｂｉｔ／ｓ）の正確な値が不明である場合に、f_1＝（ｎ／ｍ）f_0±ａ（ｎ，ｍは自然数）かつ（ｎ／ｍ）^{2} ｑ／｛ｋ＋（ｎ／ｍ）ｑ｝f_0≦ａ＜（ｎ／ｍ）^{2} ｑ／｛ｋ＋（ｎ／ｍ）ｑ－１｝f_0（ｋは自然数）を満たすように、f_1の値を掃引する
ことを特徴とするデータ信号品質評価装置。
【請求項１３】
請求項１１又は１２に記載のデータ信号品質評価装置において、
前記変数ａの値が、
【数６】

$$a=\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leq k\text{を満たす実数})$$

であり、サンプリングデータを測定順に時間軸方向に
ｄｔ＝１／（ｚf_0）
の時間間隔で表示するときに、最初のサンプリングデータから数えてｉｋ個（ｉは自然数

）ごとに時間位置を重ね合わせてサンプリングデータを表示することにより信号アイパタンを求めてデータ信号波形測定および品質評価をおこない、かつ、
重ね合わせ回数をｊ（ｊは自然数）としたときに、全サンプリングデータ数Ｎｓａｍｐに対して、ｉｋｊ≦Ｎｓａｍｐを満たす
ことを特徴とするデータ信号品質評価装置。
【請求項１４】
請求項１３に記載のデータ信号品質評価装置において、
前記変数ｉ，ｋが、ｉｋｊ≦Ｎｓａｍｐを満たし、かつ、
【数７】

$$ijk \leqq \frac{kz}{2q(k-z)}$$

を満たす値である
ことを特徴とするデータ信号品質評価装置。
【請求項１５】
請求項１４に記載のデータ信号品質評価装置において、ビットレートf_0（ｂｉｔ／ｓ）の正確な値が不明である場合に、前記サンプリングの繰り返し周波数f_1（Ｈｚ）が$f_1=(n/m)f_0 \pm a$（ｎ，ｍは自然数）かつ$(n/m)^2 q/\{k+(n/m)q\} f_0 \leqq a < (n/m)^2 q/\{k+(n/m)q-1\} f_0$（ｋは自然数）を満たし、かつ、ｉｋｊ≦Ｎｓａｍｐかつ$ikj \leqq kz/\{2q(k-z)\}$（ｉ，ｊ，Ｎｓａｍｐは自然数）を満たすように、該電気信号処理手段において、ｋの値、ｎ／ｍの値、ｑの値、のいずれか一つ以上を掃引する
ことを特徴とするデータ信号品質評価装置。
【請求項１６】
請求項１１又は１２記載のデータ信号品質評価装置において、前記変数ａの値が、
【数８】

$$a = \frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

であり、サンプリングデータを測定順に時間軸方向に
$dt=1/(zf_0)$
の時間間隔で表示するときに、最初のサンプリングデータの時間位置をｔ＝０として$t=p/f_0$（ｐは自然数）ごとに時間位置を０に戻して重ね合わせてサンプリングデータを表示することにより信号アイパタンを求めてデータ信号波形測定および品質評価をおこない、かつ、
重ね合わせ回数をｊ（ｊは自然数）としたときに、全サンプリングデータ数Ｎｓａｍｐに対して、ｐｋｊ≦Ｎｓａｍｐを満たす
ことを特徴とするデータ信号品質評価装置。
【請求項１７】
請求項１３、１４、１５、又は１６のいずれか１項に記載のデータ信号品質評価装置において、
前記電圧保持手段に保持されている該Ｎｓａｍｐ個のサンプリングデータを一度にまたは順次読み出して電気信号処理手段において信号アイパタンを求める工程を複数回繰り返し、それぞれの信号アイパタンのアイ開口を評価するアイ開口評価部を有し、該アイ開口が時間的に一致するように重ね合わせることで、データ信号波形測定および品質評価をおこ

なうための信号アイパタンを構成する全サンプリングデータ数を増やすことを特徴とするデータ信号品質評価装置。

【請求項１８】

請求項１１、１２、１３，１４、１５、１６、又は１７のいずれか１項に記載のデータ信号品質評価装置において、

前記電気信号処理手段は、データ信号品質パラメータとして振幅ヒストグラムを求める振幅ヒストグラム評価部、データ信号品質パラメータとして時間ヒストグラムを求める時間ヒストグラム評価部の両方または一方を備え、

該振幅ヒストグラムと該時間ヒストグラムが、信号アイパタンをそれぞれ振幅方向と時間方向に分割して得られるサンプリングデータ分布から求められることを特徴とするデータ信号品質評価装置。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】

本発明は、所定のビットレートを有する光または電気のデータ信号をサンプリングし、アイパタンの表示や信号品質の測定を行う際に用いて好適な高速サンプリングによるデータ信号品質評価方法および装置に関する。

【０００２】

【従来の技術】

図１０に従来の光信号品質評価装置の第１例を示す（例えば、非特許文献１、非特許文献２を参照）。この従来の光信号品質評価装置は、ビットレートがf_0（ｂｉｔ／ｓ）の光信号を電気強度変調信号に変換する光電変換手段１０１、該電気強度変調信号からクロック抽出を行うクロック抽出手段１０２、該クロック抽出手段１０２より抽出されたクロックに同期して、繰り返し周波数がf_1（Ｈｚ）（f_1＝（ｎ／ｍ）f_0＋ａ：ｎ，ｍは自然数、ａはオフセット周波数）のサンプリングクロックを発生するサンプリングクロック発生手段１０３、および電気信号処理手段１０４を有する。該電気信号処理手段１０４は、クロック抽出手段１０２を介して入力された電気強度変調信号を該サンプリングクロックによってサンプリングし、得られるサンプリング電気信号をもとにサンプリングデータ分布を逐次表示して信号アイパタンを求めて光信号品質パラメータを評価する。

【０００３】

上記の従来例に類似した第２例としては、繰り返し周波数がf_1（Ｈｚ）（f_1＝（ｎ／ｍ）f_0＋ａ：ｎ，ｍは自然数、ａはオフセット周波数）でパルス幅が光信号のタイムスロットよりも十分狭いサンプリング光パルス列を用いた光サンプリング手段の例や、サンプリングクロックを用いた光サンプリング手段の例がある（例えば特許文献１，特許文献２、非特許文献３を参照）。これらの光サンプリング手段は、光電変換手段の前段に配置される。光分岐手段により光信号を分岐し、一方の出力からクロック抽出を行うことによって得られるクロックに同期したサンプリングクロックまたはサンプリング光パルス列を用いて光サンプリングを行う。サンプリング光信号は光電変換手段によりサンプリング電気信号に変換される。電気信号処理手段ではサンプリング電気信号をもとにサンプリングデータ分布を逐次表示して信号アイパタンを求めて光信号品質パラメータを評価する。

【０００４】

【特許文献１】

特許第２６７７３７２号公報

【特許文献２】

特許第３２３９９２５号公報

【特許文献３】

欧州特許出願公開第　ＥＰ０９２０１５０Ａ２　号明細書

【非特許文献１】

“Ｈａｎｄｂｏｏｋ　ｏｆ　ＥＬＥＣＴＲＯＮＩＣ　ＴＥＳＴ　ＥＱＵＩＰＭＥＮＴ（Ｓｅｃｔｉｏｎ　５－８．ＳＡＭＰＬＩＮＧ　ＯＳＣＩＬＬＯＳＣＯＰＥ）”，ｐｐ

. 184－189, JOHN D. LENK, Prentice－Hall, Inc., Englewood Cliffs, N. J., 1971

【非特許文献2】

“Modeling of the HP－1430A Feedthrough Wide－Band (28－ps) Sampling Head”, SEDKI M. RIAD, IEEE Transactions on Instrumentation and Measurement, Vol. IM－31, No. 2, June 1982, pp. 110－115

【非特許文献3】

“100 Gbit／s optical signal eye－diagram measurement with optical sampling using organic nonlinear optical crystal”, H. Takara, S. Kawanishi, A. Yokoo, S. Tomaru, T. Kitoh and M. Saruwatari, Electronics Letters, Vol. 32, No. 24. 21st November 1996, pp. 2256－2258

【非特許文献4】

“Optical signal quality monitoring method based on optical sampling”, I. Shake, H. Takara, S. Kawanishi and Y. Yamabayashi, Electronics Letters, Vol. 34, No. 22, 29th October 1998, pp. 2152－2154

【0005】

【発明が解決しようとする課題】

従来例1におけるサンプリングクロックの繰り返し周波数は通常数十～数百ｋＨｚであり、評価に必要十分な信号アイパタンを得るのに時間がかかって光信号のワンダが問題になるので、クロック抽出が必須であった。従来例2におけるサンプリングクロックやサンプリング光パルス列を用いた光サンプリングの例では、該サンプリングクロックや該サンプリング光パルス列の繰り返し周波数は１０ＭＨｚ程度であるが、サンプリングデータ分布を求める電気信号処理を逐次行う必要があったため、実効的なサンプリングレートは低下し、評価に必要十分な信号アイパタンを得るのに時間がかかって光信号のワンダが問題になるので、クロック抽出が必須であった。

【０００６】

上述のように、従来の第１例、第２例は全てクロック抽出を必要とするため、装置規模の増大、方法や装置の複雑化、装置コストの増大が問題であった。クロック抽出を必要としない光信号品質監視装置には従来の第３例（例えば、特許文献３、非特許文献４を参照）として、非同期サンプリングを用いた光信号品質監視装置がある。しかしこの方法は非同期アイパタンをもとにした光信号強度分布を評価するため、時間方向の劣化（ジッタ、偏波分散など）に適用できるまでには至っていない。

【０００７】

本発明は、上述の点に鑑みてなされたもので、その目的は、クロック抽出部を必要としないことで装置規模の小型化、方法や装置の簡易化、装置コストの縮小を可能とし、かつ、雑音劣化や波長分散劣化のみならずジッタや偏波分散劣化などの時間方向の信号品質劣化をも監視できるデータ信号品質評価方法および装置を提供することにある。

【０００８】

【課題を解決するための手段】

上記目的を達成するため、本発明のデータ信号品質評価方法は、入力されるビットレートf_0（ｂｉｔ／ｓ）の光または電気のデータ信号とは独立に生成されるものであって、ビットレートf_0（ｂｉｔ／ｓ）とは異なる繰り返し周波数f_1（Ｈｚ）の光または電気のサンプリングパルス列を用いて、該データ信号をサンプリングし、得られる光または電気

のサンプリング信号を変換して電気のデジタルデータとしてバッファに保持する工程をＮ回（Ｎは自然数）繰り返した後に、前記バッファに保持されているＮ個のデジタルデータを一度にまたは順次読み出して電気信号処理を行うことにより、信号アイパタンを求めデータ信号波形測定および品質評価を行うことを特徴とする。

【０００９】

また、本発明のデータ信号品質評価装置は、入力されるビットレート f_0（ｂｉｔ／ｓ）の光または電気のデータ信号とは独立に生成されるものであって、ビットレート f_0（ｂｉｔ／ｓ）とは異なる繰り返し周波数 f_1（Ｈｚ）の光または電気のサンプリングパルス列を発生するサンプリングパルス列発生手段と、ビットレート f_0（ｂｉｔ／ｓ）の該データ信号を該サンプリングパルス列でサンプリングしサンプリング信号を得るデータ信号サンプリング手段と、該データ信号サンプリング手段によって得られる光または電気の該サンプリング信号を変換し、電気のデジタルデータとして複数データ分記憶する電圧保持手段と、該電圧保持手段に保持されているデジタルデータを一度にまたは順次読み込んで信号アイパタンを求め光データ信号品質パラメータを評価する電気信号処理手段と、該電圧保持手段に対してデータ取込開始と終了のトリガを与え、該電気信号処理手段にデータ読込開始・終了のトリガを与えるトリガ信号発生手段とを備えることを特徴とする。

【００１０】

【発明の実施の形態】

＜第１の実施形態＞

図１に本発明によるデータ信号品質評価装置の第１の実施形態を示す。これは請求項１０に記載の本発明に依る。本実施形態は、データ信号サンプリング手段として、電気信号電気サンプリング手段１２を用いた場合である。この場合、入力するデータ信号が電気のデータ信号であり、サンプリングパルス列発生手段としてサンプリングクロック発生手段１３を用いる。図１は特にビットレート f_0（ｂｉｔ／ｓ）の光信号を光電変換手段１１を経て電気強度変調信号に変換した後に電気信号電気サンプリング手段１２に入力する場合を示しているが、ビットレート f_0（ｂｉｔ／ｓ）の電気信号をそのまま電気信号電気サンプリング手段１２に入力する場合は光電変換手段１１は不要であり、そのような実施形態も本実施形態に含まれる。以下に本実施形態の動作について説明する。

【００１１】

ビットレート f_0（ｂｉｔ／ｓ）の光信号が光電変換手段１１を経て電気強度変調信号として、電気信号電気サンプリング手段１２に至る。一方、サンプリングクロックは、繰り返し周波数 f_1（Ｈｚ）（$f_1=(n/m)f_0+a$ または $f_1=(n/m)f_0-a$：ｎ，ｍは自然数、ａはオフセット周波数）でサンプリングクロック発生手段１３から発生される。該電気信号電気サンプリング手段１２では、該電気強度変調信号を該サンプリングクロックでサンプリングしサンプリング電気信号を得る。電圧保持手段１４では、トリガ信号発生手段１５からのデータ取込開始のトリガ信号に従って、該サンプリング電気信号のアナログ・デジタル変換（ＡＤ変換）を行い、一時的な記憶保持動作を行う。電圧保持手段１４は、該トリガ信号発生手段１５からデータ取込終了のトリガ信号が発信されるまでの間の複数のサンプリングデータを保持する。そして外部からのトリガ信号に従ってそれを出力する。ここでは例えば、キロバイト以上の容量を持つ電気バッファメモリを備え、ＭＨｚ～ＧＨｚサンプリングの機能を有した高速ＡＤ変換回路などを用いることができる。また、望ましくは、該サンプリングクロックのサンプリングゲート幅は光信号のビットレート f_0 の逆数で決まる時間の１／４以下程度がよい。

【００１２】

電圧保持手段１４において、一定時間データ取込をおこなって複数のサンプリングデータを保持した後、トリガ信号発生手段１５からデータ読込開始のトリガ信号が電気信号処理手段１６に向けて発信されると、該電気信号処理手段１６は、該データ読込開始のトリガ信号に応じて、該電圧保持手段１４から複数のサンプリングデータを読み込み、該サンプリングデータから信号アイパタンを求め、それを表示したり、雑音劣化、波長分散劣化や、ジッタ、偏波分散劣化などの時間方向の信号品質劣化等に係る所定の演算処理を行って

光信号品質パラメータを評価できるように表示したり、所定の外部装置に出力したりする。

【００１３】

ここで、サンプリングクロックの繰り返し周波数f_1は、光信号ビットレートf_0に関係した数である（ｎ／ｍ）f_0をもとに決定されるだけであり、クロック抽出などを用いて光信号のビット位相に追随することは行わない。たとえば、光信号ビットレートが、２．５Ｇｂｉｔ／ｓ、１０Ｇｂｉｔ／ｓ、４０Ｇｂｉｔ／ｓのどれかである場合を考える。この場合、サンプリングクロックの繰り返し周波数を決定するために必要な情報として、たとえばそれらのビットレートの公約数の１つである１００ＭＨｚが解っていればそれをもとにf_1を決定できる。例えばサンプリングクロックの繰り返し周波数を（１００ＭＨｚ＋ａＨｚ）で設定し、必要なサンプリングデータ数として１５０００点を仮定すれば、データ取込時間は約１５０μｓとなる。すなわちこの方法では、ワンダによるビット位相シフトのうち約１５０μｓ以内での変化だけが、評価に用いるアイパタンに影響する。一日の温度差が６０℃（１２時間）とすると１５０μｓでの温度変化は約2.1×10^{-7}℃。光信号の伝送路を形成するナイロンコーティングの石英ファイバにおけるパルス遅延量が最大約０．２ｐｓ／ｍ／℃（実測値）であることを考慮すれば、１００ｋｍの伝送路全体の温度が気温変動に伴って変化することにより生じるパルス遅延量は、１５０μｓの間に4.2×10^{-3} ｐｓとなる。これは分解能２０ｐｓ程度の電気サンプリングはもちろん、１ｐｓ程度の光信号光サンプリングでも無視できる値であるため、本方法によるアイパタンは擬似的に同期アイパタンとして評価できる。

【００１４】

なお、オフセット周波数ａの範囲としては、例えば、

【数９】

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k,\ q\text{は自然数})$$

となるように設定する。

【００１５】

ここで、ｎ／ｍ、ｋ、ｑのあらわす意味は、後述の<各実施の形態におけるアイパタンの表示例>に詳述する。

また、本発明のデータ信号品質評価装置における入力信号（データ信号）は、上述したようなビットレートf_0（ｂｉｔ／ｓ）の光信号に限定されず、ビットレートf_0（ｂｉｔ／ｓ）の電気信号であってもよい。その場合、例えば、図１に示す実施の形態では、光電変換手段１１を省略し、ビットレートf_0の入力電気信号を直接、電気信号電気サンプリング手段１２へ入力するようにすればよい。

【００１６】

また、クロック抽出などを用いて光信号（又は電気信号）のビット位相にサンプリングクロックの繰り返し周波数f_1を追随させないということは、データ信号とは独立に繰り返し周波数f_1（Ｈｚ）のサンプリング信号を生成するということである。ここで「独立」とは、データ信号とサンプリング信号とのビット位相関係が常にトラッキングされているのではない、という意味である。

【００１７】

また、電気信号処理手段１６による電圧保持手段１４からの複数のサンプリングデータの読み出しは、複数のサンプリングデータを一度に読み出すようにしてもよいし、順次に読み出すようにしてもよい。

【００１８】

＜第２の実施形態＞
図２に本発明のデータ信号品質評価装置の第２の実施形態を示す。これは請求項１０に記載の本発明に依る。本実施形態は、データ信号サンプリング手段として、光信号電気サンプリング手段２２を用いた場合である。この場合、入力するデータ信号が光のデータ信号であり、サンプリングパルス列発生手段としてサンプリングクロック発生手段２３を用いる。この場合、光信号電気サンプリング手段２２によって光のサンプリング信号（サンプリング光信号）が得られるので、該サンプリング信号を電気のデジタルデータに変換して保持するには、光電変換を行った後にアナログ・デジタル変換を行うという手順が必要である。そのため、図２では光電変換手段２１の後にアナログ・デジタル変換機能を有した電圧保持手段１４を用いる構成になっている。図２において図１と同一の構成には同一の参照符号を付けている。以下に本実施形態の動作について説明する。
【００１９】
ビットレートｆ$_0$（ｂｉｔ／ｓ）の光信号が光信号電気サンプリング手段２２に至る。一方、サンプリングクロックは、繰り返し周波数ｆ$_1$（Ｈｚ）（ｆ$_1$＝（ｎ／ｍ）ｆ$_0$＋ａまたはｆ$_1$＝（ｎ／ｍ）ｆ$_0$－ａ：ｎ，ｍは自然数、ａはオフセット周波数）でサンプリングクロック発生手段２３から発生され、該光信号電気サンプリング手段２２に至る。ここで、サンプリングクロック発生手段２３には、シンセサイズド信号発生器とコムジェネレータとの組み合わせによる電気短パルス発生などを用いることができる。ここで該サンプリングクロックの繰り返し周波数ｆ$_1$はＭＨｚ～ＧＨｚ程度の高速であるのが望ましい。また、該コムジェネレータの帯域が光信号のビットレートｆ$_0$の４倍程度まで伸びており、該電気短パルスのパルス幅が、該コムジェネレータの帯域のフーリエ変換で求められる時間幅程度に決定されることが望ましい。また、必要に応じて、該コムジェネレータの前段または後段に電気増幅器を用いることもできる。また、必要に応じて、該コムジェネレータの後段にベースバンドクリッパを用いることもできる。
【００２０】
該光信号電気サンプリング手段２２では、該光信号を該サンプリングクロックでサンプリングしビットレートｆ$_1$のサンプリング光信号を得る。該光信号電気サンプリング手段２２には、電界吸収型光変調器によるゲート動作などを用いることができる。ここで望ましくは、該光信号電気サンプリング手段２２の光信号の透過帯域は光信号ビットレートｆ$_0$程度であるとよい。また望ましくは、該光信号電気サンプリング手段２２のサンプリングゲート幅は光信号のビットレートｆ$_0$の逆数で決まる時間の１／４以下程度がよい。該サンプリング光信号は光電変換手段２１により、サンプリング電気信号に変換される。
【００２１】
電圧保持手段１４では、トリガ信号発生手段１５からのデータ取込開始のトリガ信号に従って、該サンプリング電気信号のアナログ・デジタル変換（ＡＤ変換）を行い、一時的な記憶保持動作を行う。そして該電圧保持手段１４は、該トリガ信号発生手段１５からデータ取込終了のトリガ信号が発信されるまでの間の複数のサンプリングデータを保持し、外部からのトリガ信号に従ってそれを出力する。ここでは例えば、キロバイト以上の容量を持つ電気バッファメモリを備え、ＭＨｚ～ＧＨｚサンプリングの機能を有した高速ＡＤ変換回路などを用いることができる。該電圧保持手段１４において、一定時間データ取込をおこなって複数のサンプリングデータを保持した後、トリガ信号発生手段１５からデータ読込開始のトリガ信号が電気信号処理手段１６に向けて発信されると、該電気信号処理手段１６は、核データ読込開始のトリガ信号に応じて、該電圧保持手段１４から複数のサンプリングデータを読み込み、該サンプリングデータから信号アイパタンを求め光信号品質パラメータを評価する。
【００２２】
＜第３の実施形態＞
図３に本発明のデータ信号品質評価装置の第３の実施形態を示す。これは請求項１０に記載の本発明に依る。本実施形態は、データ信号サンプリング手段として、光信号光サンプリング手段３２を用いた場合である。この場合、入力するデータ信号が光のデータ信号で

あり、サンプリングパルス列発生手段としてサンプリング光パルス列発生手段３３を用いる。この場合、光信号光サンプリング手段３２によって光のサンプリング信号（サンプリング光信号）が得られるので、該サンプリング信号を電気のデジタルデータに変換して保持するには、光電変換を行った後にアナログ・デジタル変換を行うという手順が必要である。そのため、図３では光電変換手段２１の後にアナログ・デジタル変換機能を有した電圧保持手段１４を用いる構成になっている。図３において図１または図２に示すものと同一の構成には同一の参照符号を付けている。以下に本実施形態の動作について説明する。

【００２３】
ビットレートｆ$_0$（ｂｉｔ／ｓ）の光信号が光信号光サンプリング手段３２に至る。一方、サンプリング光パルス列は、繰り返し周波数ｆ$_1$（Ｈｚ）（ｆ$_1$＝（ｎ／ｍ）ｆ$_0$＋ａまたはｆ$_1$＝（ｎ／ｍ）ｆ$_0$－ａ：ｎ，ｍは自然数、ａはオフセット周波数）でサンプリング光パルス列発生手段３３から発生され、該光信号光サンプリング手段３２に至る。ここで該サンプリング光パルス列は、光信号のビットレートｆ$_0$の逆数で決まる時間よりも十分狭いパルス幅を有する。該サンプリング光パルス列発生手段３３には、利得スイッチ型のレーザーダイオードや、ファイバリングレーザ、モード同期レーザーダイオードなどを用いることができる。ここで該サンプリング光パルス列の繰り返し周波数ｆ$_1$はＭＨｚ～ＧＨｚ程度の高速であるのが望ましい。また、該サンプリング光パルス列のパルス幅は、光伝号のビットレートｆ$_0$の逆数で決まる時間の１／４程度以下が望ましい。

【００２４】
該光信号光サンプリング手段３２では、該光信号を該サンプリング光パルス列でサンプリングしサンプリング光信号を得る。ここで、光信号光サンプリング手段３２には、光信号とサンプリング光パルス列との間の非線形光学効果を利用することができ、ＫＴＰ（ＫＴｉＯＰＯ$_4$）やＡＡＮＰ（２－ａｄａｍａｎｔｙｌａｍｉｎｏ－５－ｎｉｔｒｏｐｙｒｉｄｉｎｅ）やＰＰＬＮ（Ｐｅｒｉｏｄｉｃａｌｌｙ Ｐｏｌｅｄ Ｌｉｔｈｉｕｍ Ｎｉｏｂａｔｅ）などの非線形光学媒質を用いることができる。また、非線形光学効果としては、ＳＦＧ（和周波光発生）、ＳＨＧ（第二高調波発生）、ＦＷＭ（四光波混合）などを用いることができる。

【００２５】
該サンプリング光信号は光電変換手段２１により、サンプリング電気信号に変換される。電圧保持手段１４では、トリガ信号発生手段１５からのデータ取込開始のトリガ信号に従って、該サンプリング電気信号のアナログ・デジタル変換（ＡＤ変換）を行い、一時的な記憶保持動作を行う。該トリガ信号発生手段１５からデータ取込終了のトリガ信号が発信されるまでの間の複数のサンプリングデータを保持する。そして外部からのトリガ信号に従ってそれを出力する。ここでは例えば、キロバイト以上の容量を持つ電気バッファメモリを備え、ＭＨｚ～ＧＨｚサンプリングの機能を有した高速ＡＤ変換回路などを用いることができる。該電圧保持手段１４において、一定時間データ取込をおこなって複数のサンプリングデータを保持した後、トリガ信号発生手段１５からデータ読込開始のトリガ信号が電気信号処理手段１６に向けて発信されると、該電気信号処理手段１６は、該データ読込開始のトリガ信号に応じて、該電圧保持手段１４から複数のサンプリングデータを読み込み、該サンプリングデータから信号アイパタンを求め光信号品質パラメータを評価する。

【００２６】
＜第４の実施形態＞
本実施形態では、信号ビットレートｆ$_0$の正確な値がわからない場合の評価手順例について述べる。まず、信号フォーマットがわかっている場合は、たとえばＳＤＨならば、信号ビットレートは、２．４８８３２Ｇｂｉｔ／ｓ、９．９５３２８Ｇｂｉｔ／ｓ、３９．８１３１２Ｇｂｉｔ／ｓ・・・のいずれかであると考えられる。しかし、実際の信号ビットレートは正確にはｄｆ（Ｈｚ）だけずれていることが考えられ、たとえばＳＤＨでは、ｄｆ＝±２００ｐｐｍを許容している。実際にｄｆだけ信号ビットレートがずれているとして、サンプリングクロックの繰り返し周波数を、ｄｆを考慮せずに、２．４８８３２Ｇｂ

ｉｔ／ｓ、９．９５３２８Ｇｂｉｔ／ｓ、３９．８１３１２Ｇｂｉｔ／ｓの公約数などをもとに決定すると、f_1にもｄｆを考慮していない分だけのずれが生じる。そのf_1が、
$f_1=(n/m)f_0 \pm a$（ｎ，ｍは自然数）かつ$(n/m)^2 q/\{k+(n/m)q\}f_0 \leq a < (n/m)^2 q/\{k+(n/m)q-1\}f_0$　（ｋは自然数）を満たしていればよく、満たしていない場合は、f_1の値を掃引したり、$ikj \leq Nsamp$かつ$ikj \leq kz/\{2q(k-z)\}$　（ｉ，ｊ，Ｎｓａｍｐは自然数）を満たすように、f_1の値、ｋの値、ｎ／ｍの値、ｑの値、のいずれか一つ以上を掃引することにより、開いたアイパタンの測定を可能にする。なお、ｎ／ｍ，ｋ，ｑ，ｚの表す意味については、後述する＜各実施の形態におけるアイパタンの表示例＞で詳述する。そして、これらのパラメータを掃引する方法は、信号フォーマットにより信号ビットレートがある程度わかる場合だけでなく、信号ビットレートがまったくわからない場合にも適用できる。しかし、その場合、f_1の可変幅に対する要求は大きくなる。
f_1の掃引なしにアイパタン測定を可能とする条件は、
$f_1 \geq (2 \cdot f_0 \cdot Nsamp \cdot |df|)^{1/2}$
であり、たとえば、f_0＝９．９５３２８Ｇｂｉｔ／ｓ、ｄｆ＝２００ｐｐｍ、Ｎｓａｍｐ＝２５０の場合、$f_1 \geq$１ＧＨｚオーダーとなり、サンプリング速度を高速にすることにより、信号ビットレートを正確に知ることができない場合でもアイパタン測定が可能になる。

【００２７】
＜各実施形態による品質評価例＞
図４ないし図８を参照して本発明の第１ないし第４の実施形態による品質評価例について説明する。同期アイパタンの典型的な例と評価パラメータの例を示している。

【００２８】
図４はＮＲＺ信号（Ｎｏｎ－Ｒｅｔｕｒｎ－ｔｏ－Ｚｅｒｏ信号）のアイパタンの例である。強度方向のアイ開口が最大となる時間を中心にしてｄｔの時間窓を設定したときの振幅ヒストグラムを示しており、マーク、スペースの分布それぞれについて、平均値μ_1，μ_0、標準偏差σ_1，σ_0を評価している。

【００２９】
また、
$Q=|\mu_1-\mu_0|/\sigma_1+\sigma_0$
で求められるＱ値を評価パラメータとすることもできる。ここで、$|\mu_1-\mu_0|$は平均値μ_1、μ_0の差の絶対値を表す。

【００３０】
Ｑ値からは、
ＢＥＲ＝ｅｒｆｃ（Ｑ）
を用いてビット誤り率を見積もることができる。ここで、ＢＥＲはビット誤り率（Ｂｉｔ　Ｅｒｒｏｒ　Ｒａｔｅ）、ｅｒｆｃは誤差補関数を表す。

【００３１】
図５はＲＺ信号（Ｒｅｔｕｒｎ　ｔｏ　ｚｅｒｏ信号）のアイパタンの例である。平均値μ_1，μ_0、標準偏差σ_1，σ_0、Ｑ値の評価の仕方は上述したＮＲＺの場合と同様である。

【００３２】
図６はＮＲＺ信号のアイパタンの例である。ｄｔの時間窓をアイパタンのクロスポイントを中心として設定したときの振幅ヒストグラムを示しており、マーク、スペースの分布とクロスポイント付近の頻度分布について、それぞれ平均値μ_1，μ_0，μ_{cross}を評価している。

【００３３】
ここで例えば、
$R_{cross}=|\mu_{cross}-\mu_0|/|\mu_1-\mu_0|$
はクロスポイントの振幅強度のずれを示しており、波長分散などによるパルス広がりの影

響を評価するパラメータとなる。

【００３４】

図７はＮＲＺ信号のアイパタンの例である。時間幅ｄｔ、強度幅ｄＩで囲まれた部分の時間ヒストグラムを示しており、標準偏差σ_tを評価している。σ_tはジッタの影響を評価するパラメータとなる。

【００３５】

図８はＲＺ信号のアイパタンの例である。左部の図は強度方向のアイ開口が最大となる時間を中心にしてdt_aの時間窓を設定したときの振幅ヒストグラムを示しており、マーク、スペースの分布それぞれについて、平均値μ_1，μ_0を評価している。上部の図は、$|\mu_1-\mu_0|/2$の値を中心とした強度幅ｄＩと時間幅ｄｔで囲まれた部分の時間ヒストグラムを示しており、標準偏差σ_tと平均値の差T_{FWHM}を評価している。σ_tはジッタの影響を評価するパラメータとなる。T_{FWHM}はＲＺパルスの半値全幅を示しており、波長分散などによるパルス広がりを評価するパラメータとなる。

【００３６】

この他、時間幅ｄｔ、頻度幅ｄＩのウインドウを任意に設定することで、ＰＭＤ（偏波モード分散）による劣化の評価なども可能である。

【００３７】

<各実施の形態におけるアイパタンの表示例>

表示については、例えば、複数のサンプリングデータをサンプリングした順にそのままディスプレイに表示することができる。この場合、必ずしも全ての点を時系列に並べるのではなく、ある周期でもう一度時間ゼロのところから重ね書きすることができる。それをサンプリング点全部について繰り返すことでアイパタンの表示を行うことができる。

【００３８】

以下、重ね書きする周期について説明する。ここでは、データ信号のビットレートがf_0（ｂｉｔ／ｓ）で、サンプリングの繰り返し周波数f_1（Ｈｚ）が、$f_1=(n/m)f_0+a$または$f_1=(n/m)f_0-a$（ｎ，ｍは自然数、ａはオフセット周波数）で表されるときに、ａが、

【数１０】

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q}f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q}f_0 \qquad (k, q\text{は自然数})$$

の条件を満たす場合について説明する。

ここでｎ／ｍは、f_0とf_1の比に関係する値であって、たとえばｎ／ｍが１／１００であり、f_0 が１０（Ｇｂｉｔ／ｓ）である場合は、f_1は約１００（ＭＨｚ）となり、データ信号の約１００ビットに対してサンプリング点が１点得られる程度のサンプリング頻度であることを表す。また、ｋは、重ね書きする周期に関係する値であって、サンプリング点数ｋ個ずつ重ね書きすることを表す。また、ｑは、ｋ個のサンプリング点を時系列に並べたときに、データ信号の何ビット分を再現するかを表す値である。以下では一例として、$f_1=(n/m)-a$の場合について、各サンプリングデータに対応する点Ｐ１～Ｐ８のプロット例について図９（ａ）～（ｄ）を参照して説明する。図９（ａ）はデータ信号波形を示す図（ただし図９（ａ）では点Ｐ１～Ｐ５のみ図示）であり、図９（ｂ）～（ｄ）はそのプロット例を示す図である。また、各変数は、ｎ／ｍ＝１，ｋ＝４，ｑ＝１を満たすものとする。

【００３９】

上記の場合、オフセット周波数ａ（$=\pm(f_1-f_0)$）は、$(1/5)f_0 \leqq a < (1/4)f_0$の範囲の値となる。つまり、$1/4/f_0 \leqq 1/f_1-1/f_0 < 1/3/f$

$_0$であり、Δｔ（＝１／ｆ$_1$－１／ｆ$_0$）がｆ$_0$の逆数である１タイムスロットの１／４よりも大きくて１／３よりも小さく設定されているということである。点Ｐ１～Ｐ４までは、順に並べることによって１タイムスロット内の波形を再現できる（図９（ｂ））。

【００４０】

そして、この例では、点Ｐ５は点Ｐ４に続いてプロットするのではなく、時間ゼロに戻ってプロットするものとする。ここで、重ね合わせ方は二通りある。

【００４１】

（１）第１の重ね合わせ方は、図９（ｃ）に示すように、点Ｐ５の時間位置を点Ｐ１の時間位置に合わせることである。点Ｐ５の時間位置を点Ｐ１に合わせると２回目の重ね合わせの波形は、１回目の波形から少し時間的にずれたものになる。３回目、４回目と同様に重ね合わせていくと、少しずつずれが大きくなって行くので、重ね合わせ回数が増えるとだんだんアイが閉じていくことになる。この重ね合わせを実現するのに必要な情報は、ｎ／ｍの値だけである。サンプリングクロックはローカルに設定できるので、ｋは自然数の範囲で任意に決められて、それに応じて重ね書きの周期が決まる。ｋは自然数であるが、波形が複雑だと大きい方が波形の再現には好ましいといえる。

【００４２】

（２）第２の重ね合わせ方は、図９（ｄ）に示すように、点Ｐ５の時間位置を１／ｆ$_0$の整数倍を基準に合わせることである。点Ｐ５の時間位置を、１／ｆ$_0$の整数倍を基準に合わせれば、２回目の重ね合わせの波形は、１回目の波形と重なったものになる。そのかわり、ｆ$_0$の絶対値を知る必要がある。

【００４３】

さて、（１）の方法において、点Ｐ５の時間位置を点Ｐ１と同じに合わせたときのずれを見積る。もし、ａ＝（１／４）ｆ$_0$であれば、点Ｐ５は１／ｆ$_0$の周期で点Ｐ１に一致するので、４点ずつ重ね書きする（または４の倍数で重ね書きする）のであれば無限に続けてもきれいなアイパタンが得られる。しかしこの場合、上記のａの範囲を定める式から分かるように、ａは（１／４）ｆ$_0$から少しずれている。

【００４４】

ここで、ｚをｋ－１＜ｚ≦ｋを満たす実数とすると、

【数１１】

$$a=\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q}f_0$$

であり、今の場合ｎ／ｍ＝１，ｑ＝１なので、ｚを３＜ｚ＜４を満たす実数としてａ＝｛１／（ｚ＋１）｝ｆ$_0$となる。これを用いて計算すると、ａ＝（１／４）ｆ$_0$の場合と比べて、波形を重ね合わせていくときに生じるずれの大きさΔＴは、ΔＴ＝（４－ｚ）／（ｚｆ$_0$）である。すなわち、一般的に、重ね合わせの周期をｉｋ（ｉは自然数、例ではｉ＝１）としたときにΔＴ＝ｑ（ｋ－ｚ）ｉ／（ｚｆ$_0$）となる。逆にいえば、２回、３回と重ねるごとにΔＴずつ時間方向にずれながら書かれていくということになる。そのずれの累積がｆ$_0$の逆数の１タイムスロットの半分になると完全にアイパタンは閉じてしまうので、それがずれの上限となる。一度に測定するサンプリング点数をＮｓａｍｐとし、重ね書き回数をｊとするとｉｋｊ≦Ｎｓａｍｐである。よって、ずれの累積値をＳｕｍ［ΔＴ］とすると、Ｓｕｍ［ΔＴ］は、

【数１２】

$$Sum[\Delta T] = \frac{q(k-z)ij}{zf_0}$$

となる。
【００４５】
これが１／ｆ$_0$の半分以下になるのがアイ開口評価を可能とする条件なので、
【数１３】

$$\frac{(k-z)ijq}{zf_0} \leqq \frac{1}{2f_0}$$

つまり
【数１４】

$$ikj \leqq \frac{zk}{2q(k-z)}$$

を満たすサンプリング点数の範囲では、ローカルなクロックを用いてもアイ開口が評価できるということになる。
【００４６】
すなわち、ａの値が、
【数１５】

$$\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

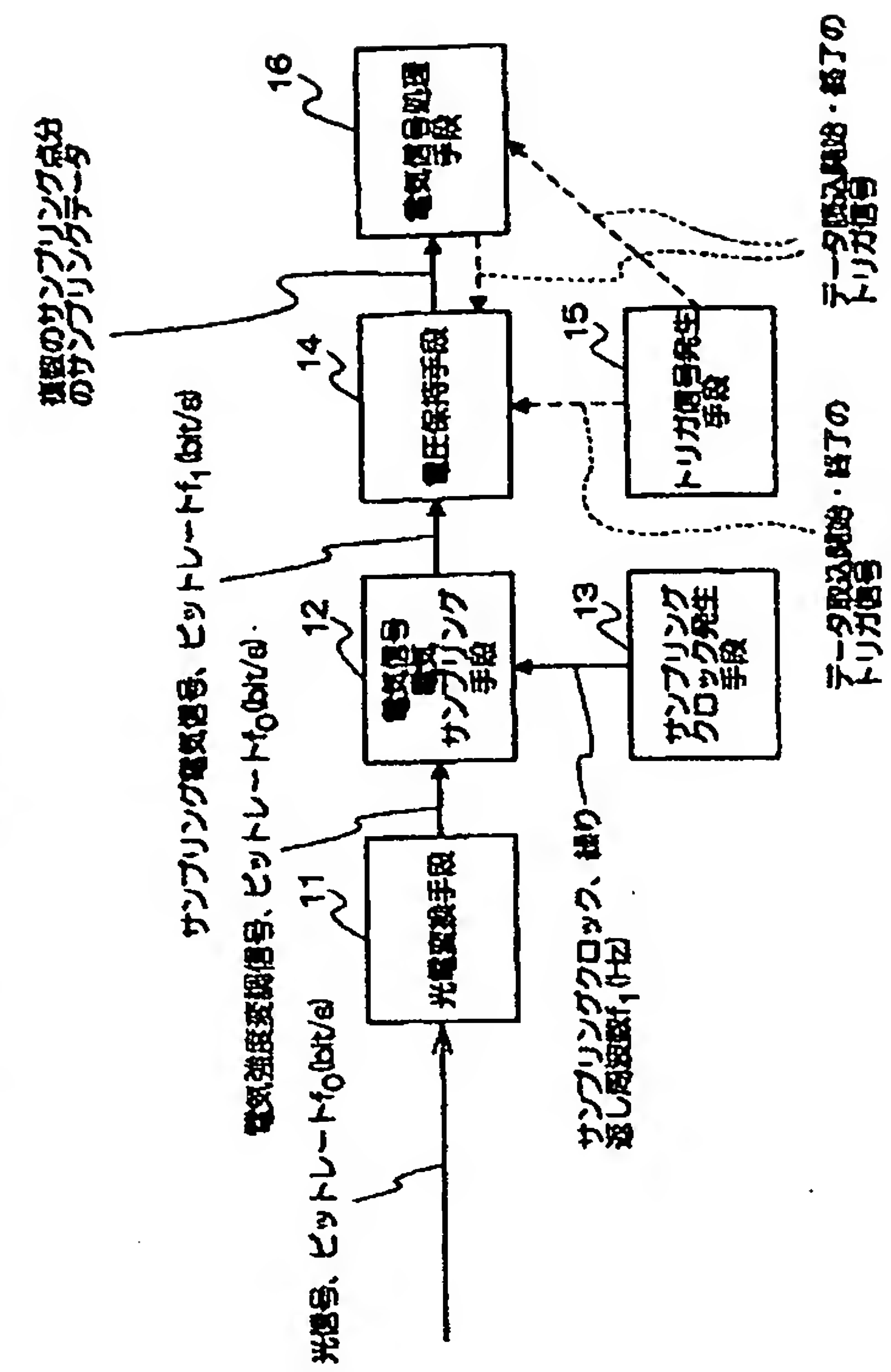
であり、Ｎｓａｍｐ個のサンプリングデータを測定順に時間軸方向にｄｔ＝１／（ｚｆ$_0$）の時間間隔で表示するときに、最初のサンプリングデータの時間位置をｔ＝０としてｔ＝ｐ／ｆ$_0$（ｐは自然数）ごとに時間位置を０に戻して重ね合わせてサンプリングデータを表示することにより信号アイパタンを求めてデータ信号波形測定および品質評価をおこなう場合、重ね合わせ回数をｊ（ｊは自然数）としたときに、全サンプリングデータ数Ｎｓａｍｐに対して、ｐｋｊ≦Ｎｓａｍｐを満たすことでデータ信号品質評価を行うことができる。
【００４７】
さらにそれを発展させると、上記のようにしてＮｓａｍｐのデータ取込とアイパタン表示を行うことをｊ回繰り返し、それぞれのアイ開口の最大点を基準にｊ個のアイパタンを重ね合わせてから評価することができる。こうすれば、実効的に評価に用いるサンプリング点数を増やすことができ、より評価の不確定性を低減できる。
【００４８】
【発明の効果】
以上説明したように本発明によれば、クロック抽出部を必要としないために装置規模の小型化、方法や装置の簡易化、装置コストの縮小が可能となり、かつ、高速サンプリングおよびバッファを用いたデータ取込をおこなうことにより、同期手段を用いないにもかかわらず、ワンダの影響をなくした疑似的同期光信号アイパタンを得ることができて、雑音劣化や波長分散劣化のみならずジッタや偏波分散劣化などの時間方向の信号品質劣化をも監視できるデータ信号品質評価方法および装置を提供することができる。

【００４９】
また、本発明では、光サンプリング法を用いることで、電気サンプリングを用いる方法に比べて適用できる光信号ビットレートが広範囲となる。

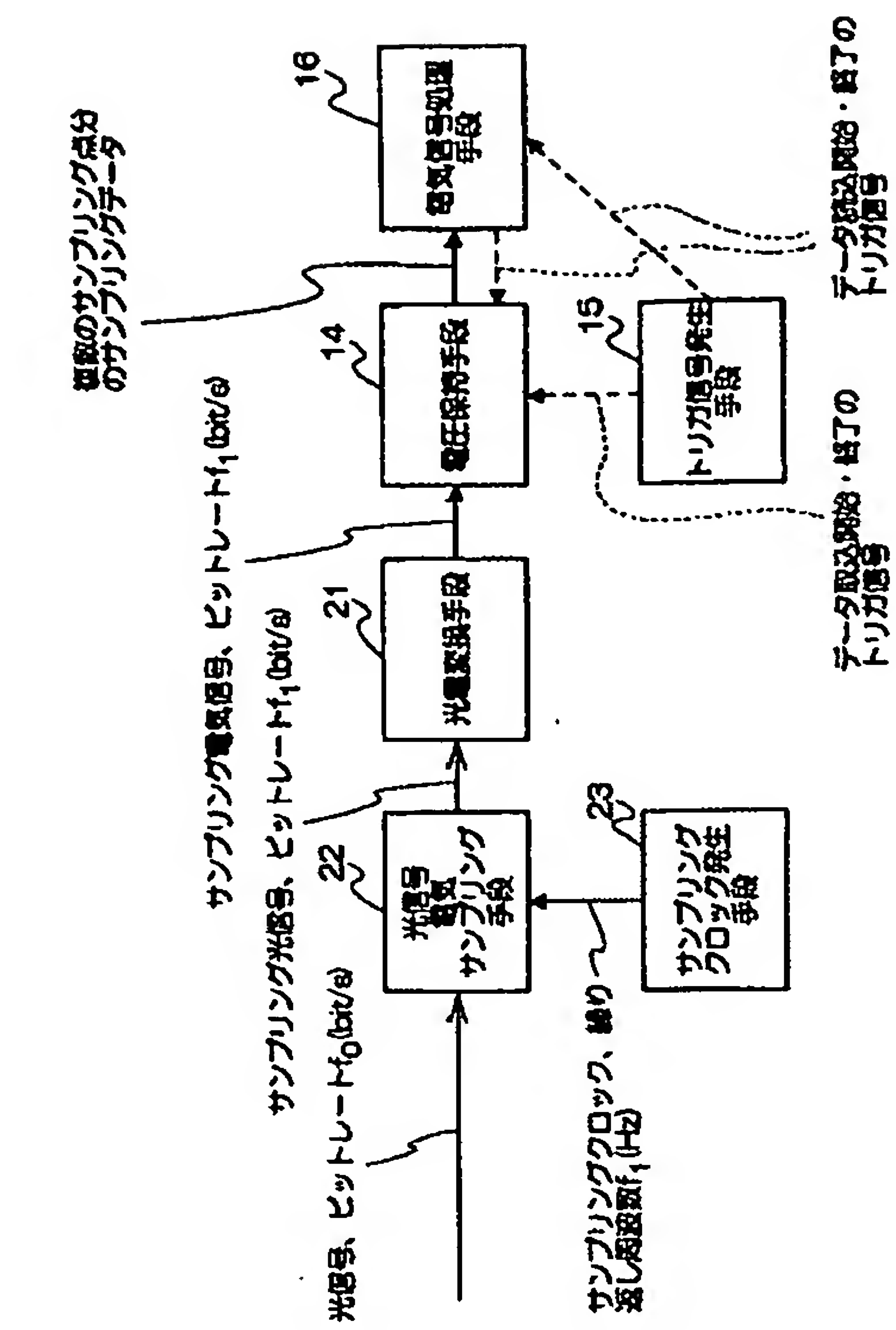
【図面の簡単な説明】
【図１】本発明の第１の実施の形態の構成を示すブロック図である。
【図２】本発明の第２の実施の形態の構成を示すブロック図である。
【図３】本発明の第３の実施の形態の構成を示すブロック図である。
【図４】図１〜図３に示す実施の形態によるデータ信号品質評価例の一例を説明するための図である。
【図５】図１〜図３に示す実施の形態によるデータ信号品質評価例の他の例を説明するための図である。
【図６】図１〜図３に示す実施の形態によるデータ信号品質評価例の他の例を説明するための図である。
【図７】図１〜図３に示す実施の形態によるデータ信号品質評価例の他の例を説明するための図である。
【図８】図１〜図３に示す実施の形態によるデータ信号品質評価例の他の例を説明するための図である。
【図９】図１〜図３に示す実施の形態によるデータプロット例を説明するための図である。
【図１０】従来例の構成を示すブロック図である。

【符号の説明】
１１　光電変換手段
１２　電気信号電気サンプリング手段
１３　サンプリングクロック発生手段
１４　電圧保持手段
１５　トリガ信号発生手段
１６　電気信号処理手段
２１　光電変換手段
２２　光信号電気サンプリング手段
２３　サンプリングクロック発生手段
３２　光信号光サンプリング手段
３３　サンプリング光パルス列発生手段

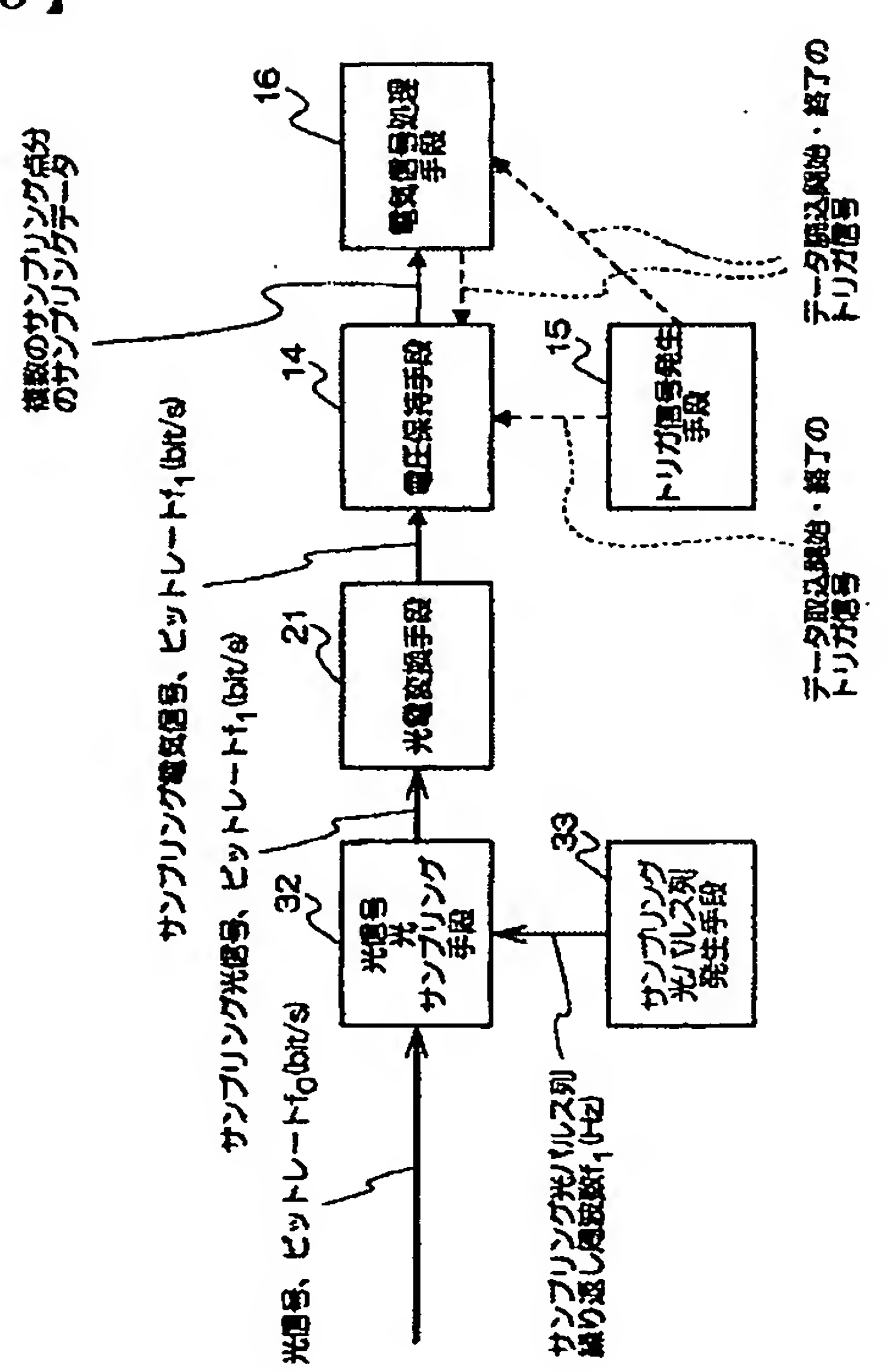
【図１】


光信号、ビットレートf0(bit/s)
11
光電変換手段
電気強度変調信号、ビットレートf0(bit/s)
12
電気信号 電気 サンプリング 手段
13
サンプリングクロック発生手段
サンプリングクロック、繰り返し周波数f1(Hz)
サンプリング電気信号、ビットレートf1(bit/s)
14
電圧保持手段
15
トリガ信号発生手段
データ取込開始・終了のトリガ信号
複数のサンプリング点分のサンプリングデータ
16
電気信号処理手段
データ取込開始・終了のトリガ信号

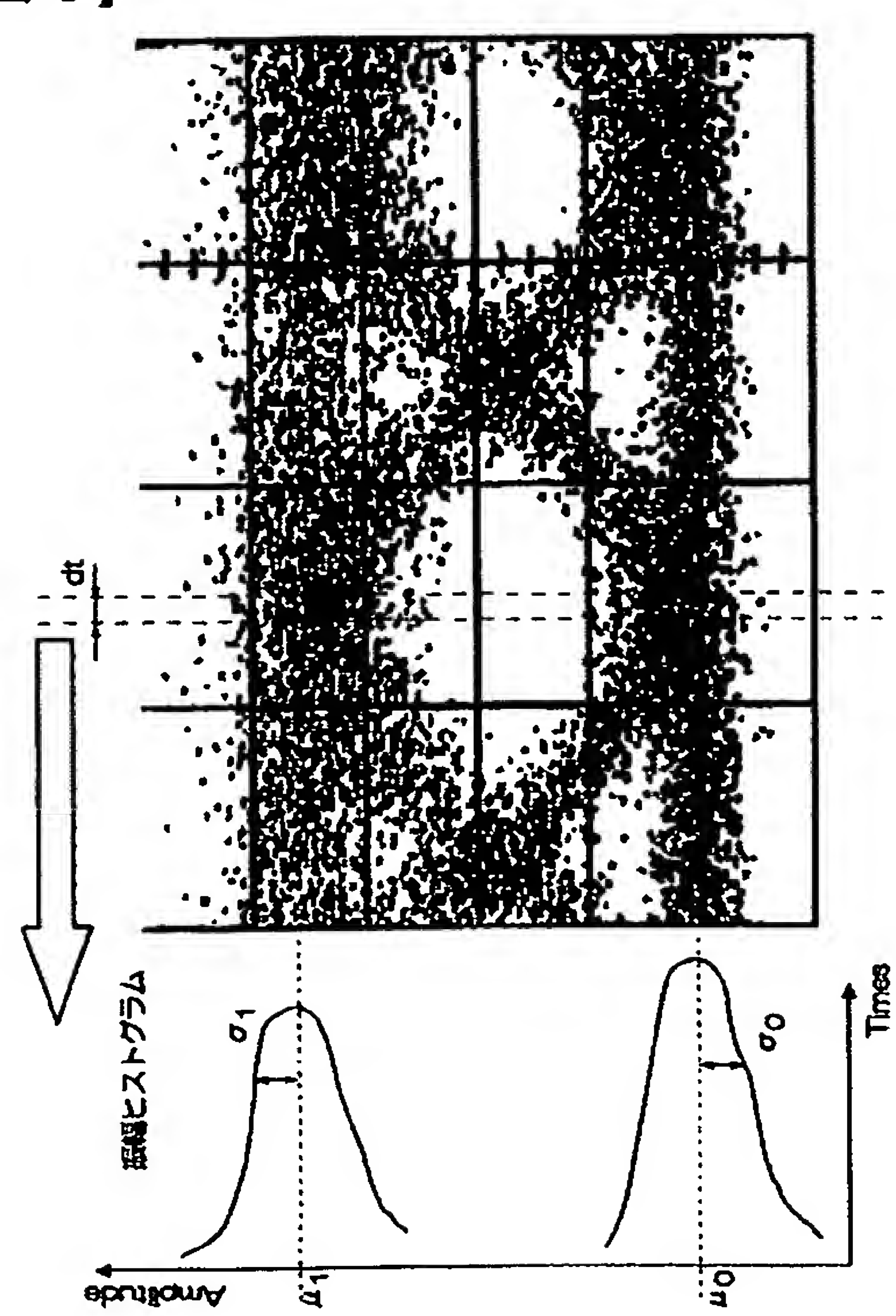
【図２】


光信号、ビットレートf0(bit/s)
22
光信号 電気 サンプリング 手段
23
サンプリングクロック発生手段
サンプリングクロック、繰り返し周波数f1(Hz)
サンプリング光信号、ビットレートf1(bit/s)
21
光電変換手段
サンプリング電気信号、ビットレートf1(bit/s)
14
電圧保持手段
15
トリガ信号発生手段
データ取込開始・終了のトリガ信号
複数のサンプリング点分のサンプリングデータ
16
電気信号処理手段
データ取込開始・終了のトリガ信号

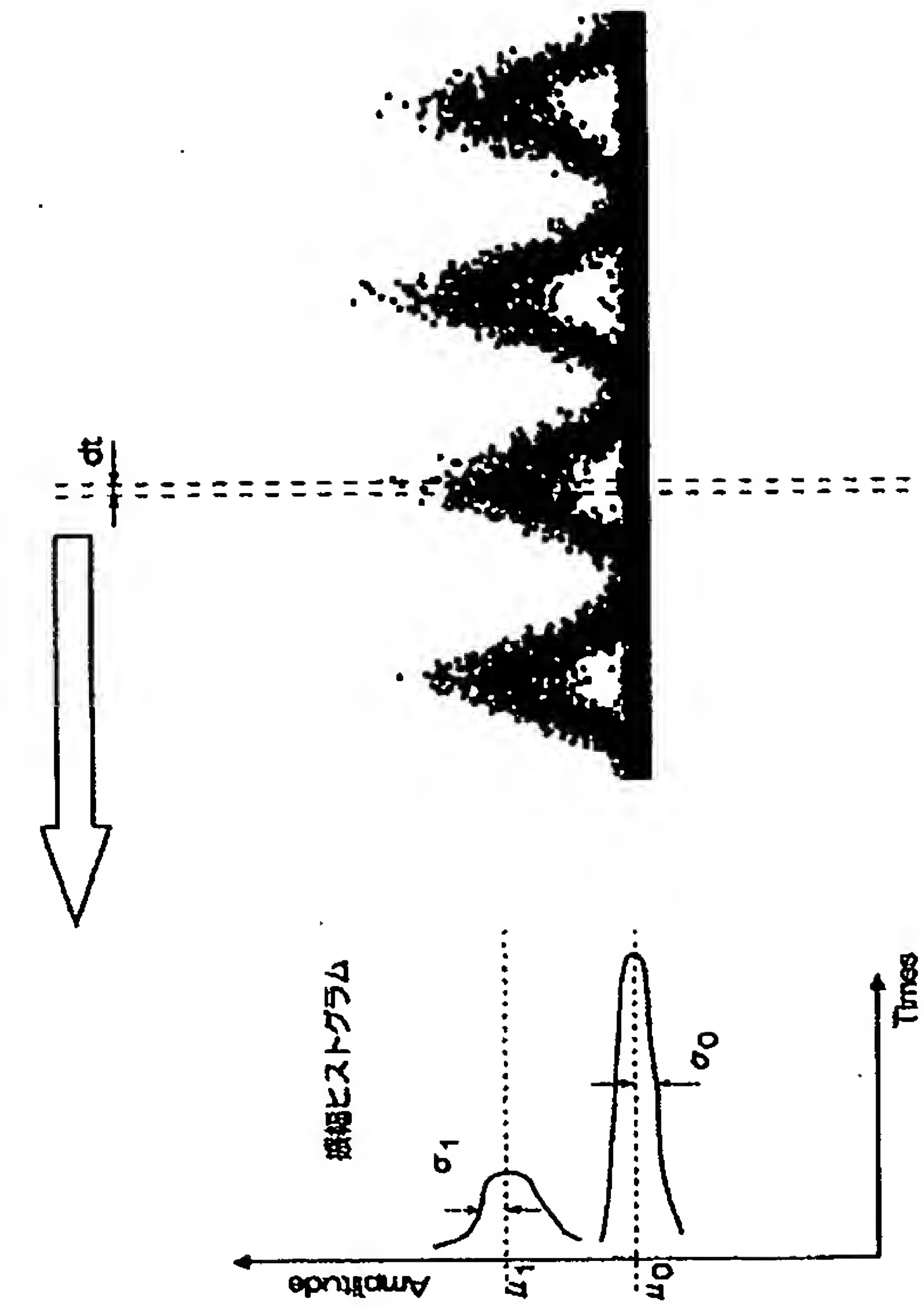
【図３】


光信号、ビットレートf0(bit/s)
32
光信号 光 サンプリング 手段
33
サンプリング光パルス列発生手段
サンプリング光パルス列繰り返し周波数f1(Hz)
サンプリング光信号、ビットレートf1(bit/s)
21
光電変換手段
サンプリング電気信号、ビットレートf1(bit/s)
14
電圧保持手段
15
トリガ信号発生手段
データ取込開始・終了のトリガ信号
複数のサンプリング点分のサンプリングデータ
16
電気信号処理手段
データ取込開始・終了のトリガ信号

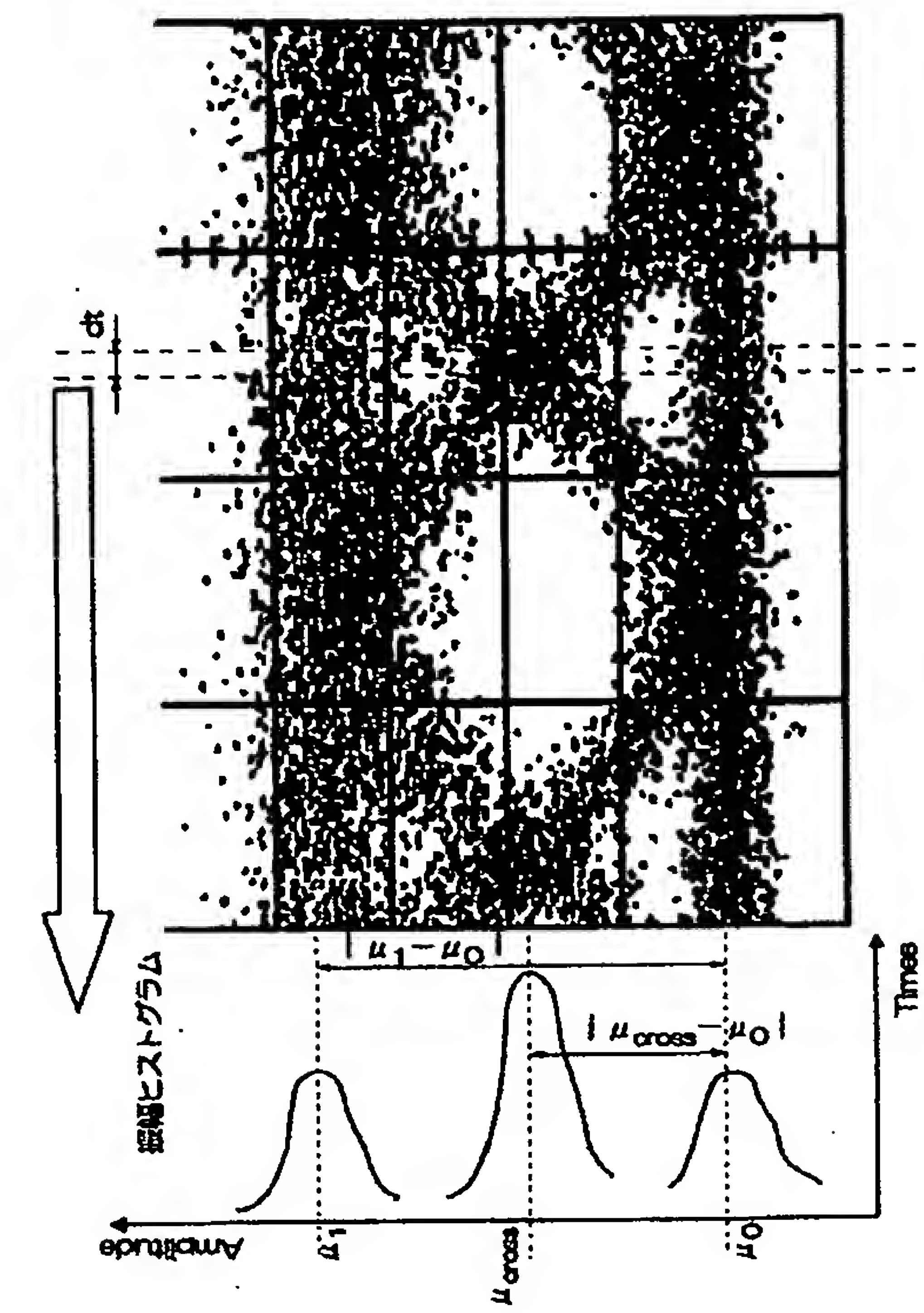
【図４】


dt
振幅ヒストグラム
σ1
σ0
μ1
μ0
Amplitude
Times

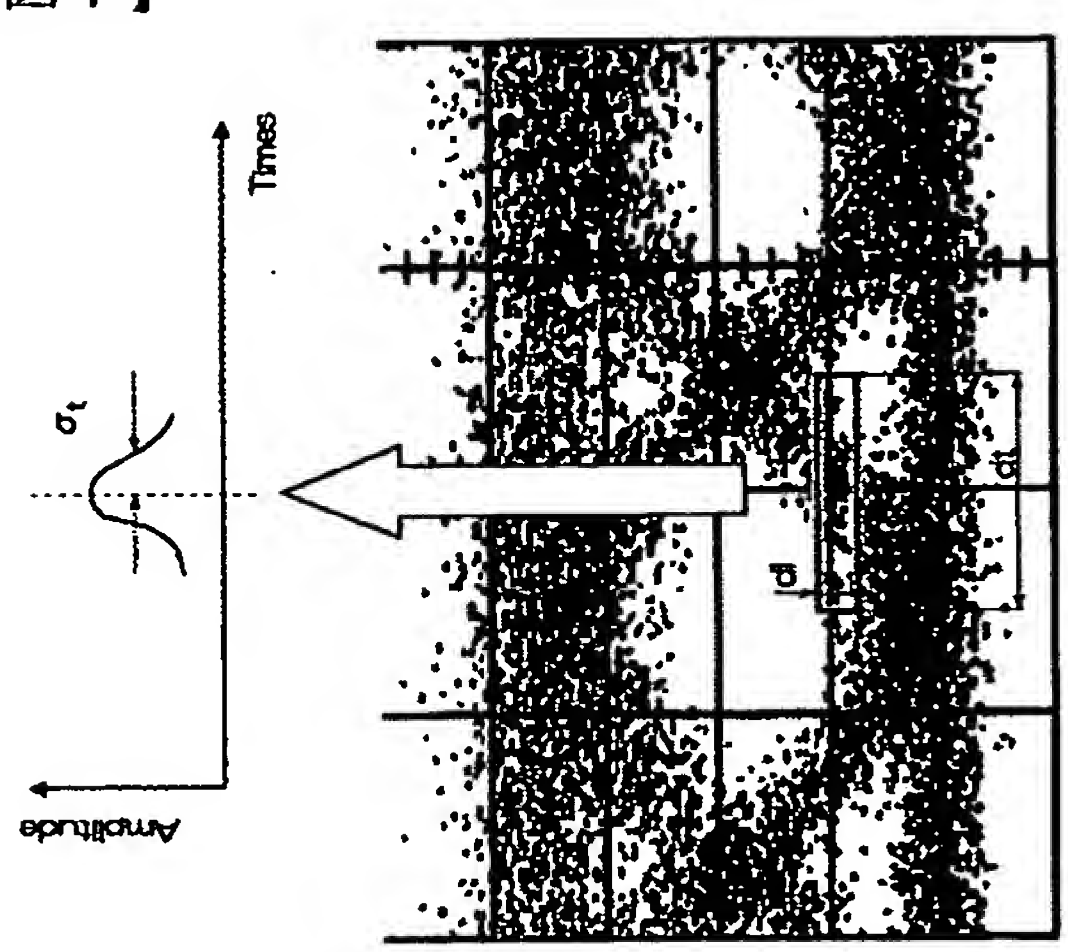
【図5】


dt
振幅ヒストグラム
Times
Amplitude
σ_1
σ_0
μ_1
μ_0

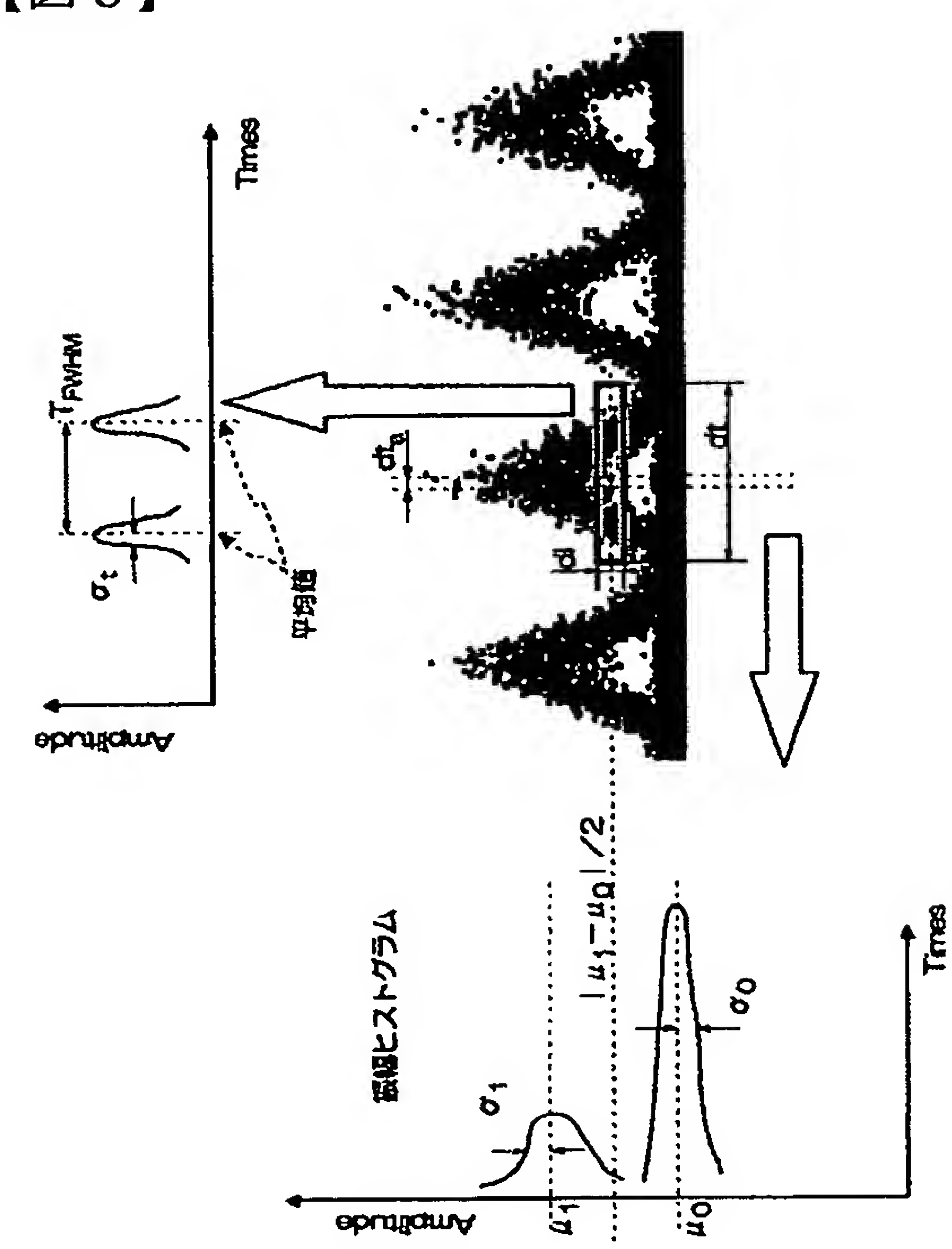
【図6】


dt
振幅ヒストグラム
Times
Amplitude
$\mu_1-\mu_0$
$|\mu_{cross}-\mu_0|$
μ_1
μ_{cross}
μ_0

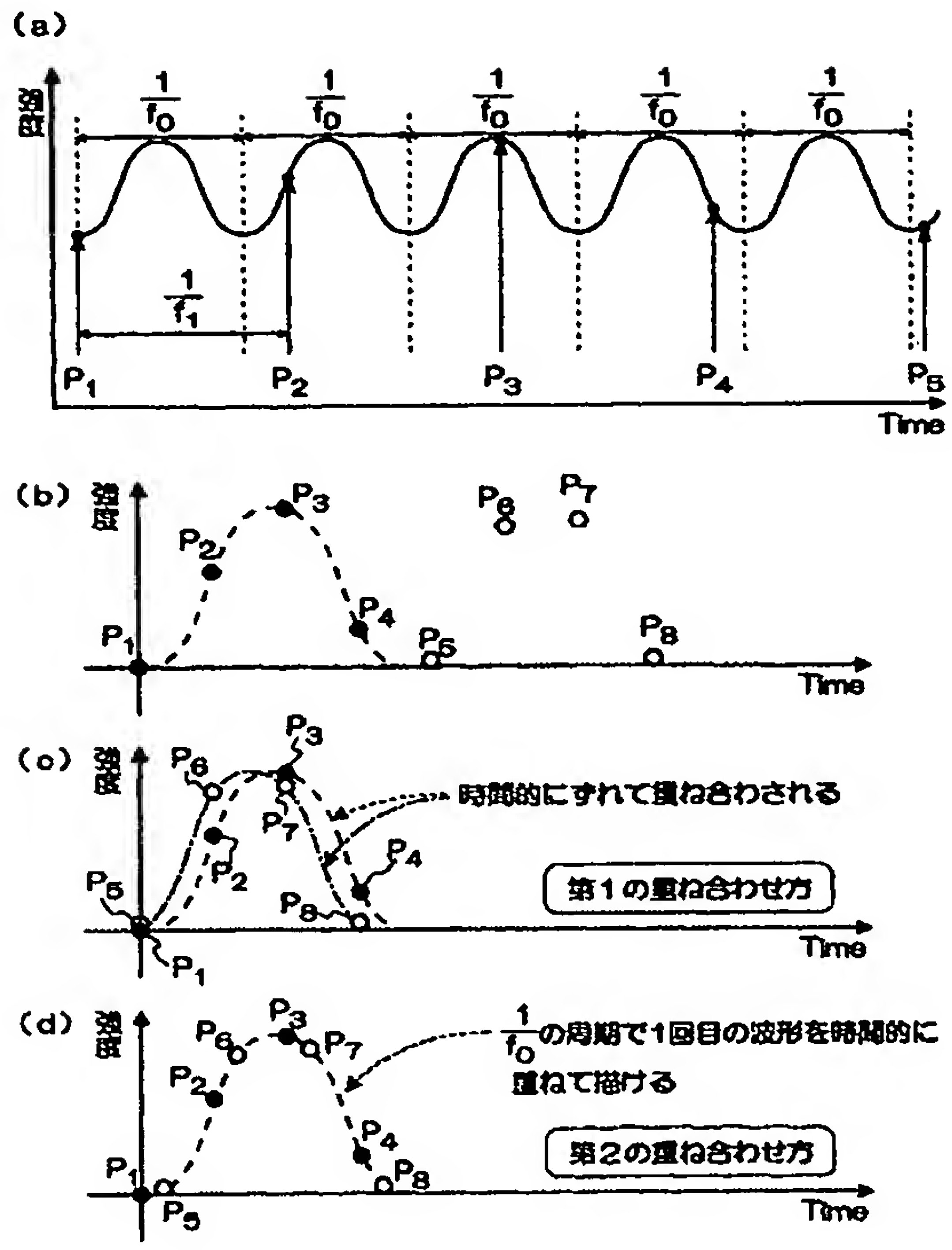
【図7】


Times
Amplitude
σ_t
dt

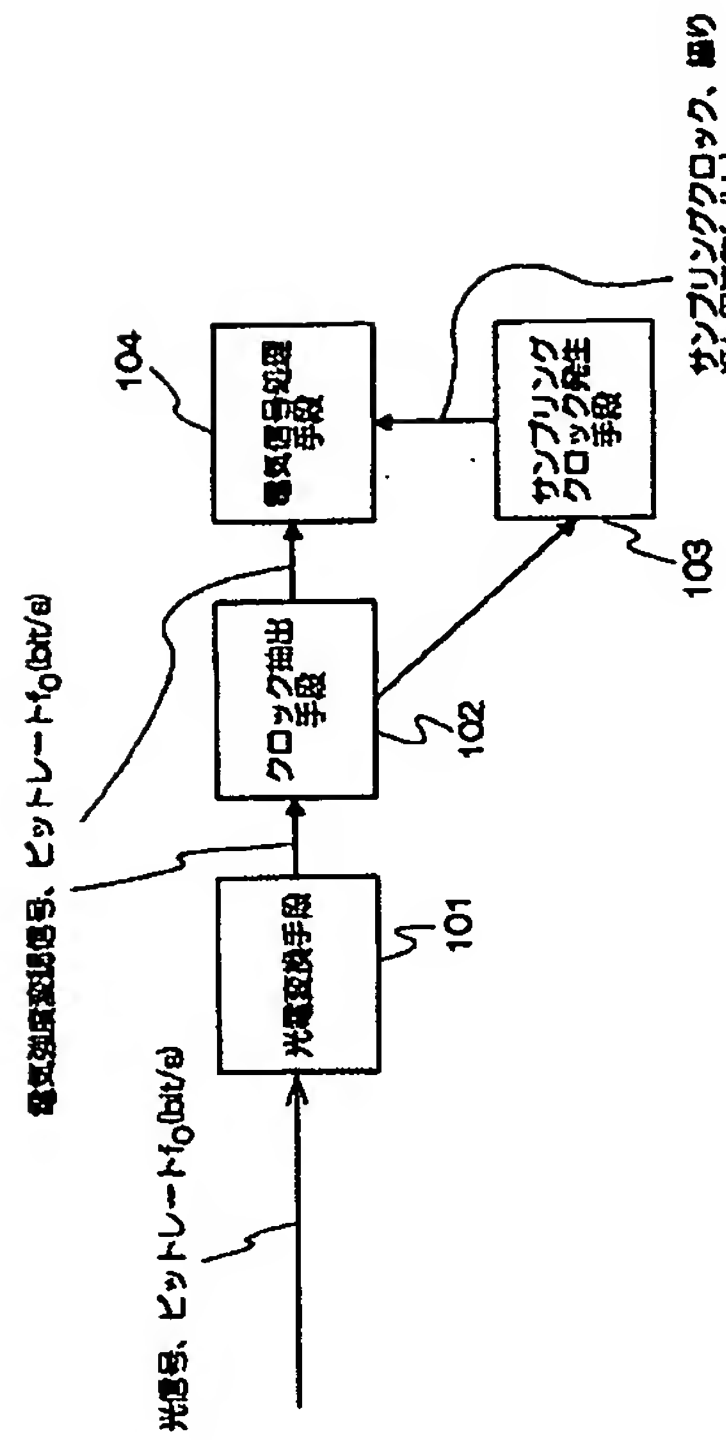
【図8】


Times
Amplitude
T_{FWHM}
σ_t
平均値
dt
振幅ヒストグラム
$|\mu_1-\mu_0|/2$
σ_1
σ_0
μ_1
μ_0

【図９】


(a)
(b)
(c)
(d)
Time
時間的にずれて重ね合わされる
第1の重ね合わせ方
の周期で1回目の波形を時間的に重ねて描ける
第2の重ね合わせ方

【図１０】


光信号、ビットレートf0(bit/s)
光電変換手段
101
電気強度変調信号、ビットレートf0(bit/s)
クロック抽出手段
102
サンプリングクロック発生手段
103
電気信号処理手段
104
サンプリングクロック、繰り返し周波数f1(Hz)

フロントページの続き

Ｆターム(参考) 5K029 AA18 CC01 CC04 KK25
5K102 AA11 AA15 AA17 LA02 LA11 LA38 MH32

【要約の続き】
読込開始・終了のトリガを与えるトリガ信号発生手段とを備える。
【選択図】 図１

* NOTICES *

CLAIMS

[Claim(s)]
[Claim 1]
After repeating the process which the light of a bit rate f0 (bit/s) inputted or an electric data signal is generated independently, and samples this data signal, changes the sampling signal of the light or the electrical and electric equipment obtained using the light of a different repeat frequency f1 (Hz) from a bit rate f0 (bit/s), or an electric sampling pulse train, and is held to a buffer as electric digital data N time (N is the natural number),
the digital data of N individual currently held at said buffer -- once -- or the data signal quality evaluation approach characterized by performing data signal wave measurement and quality evaluation in quest of a signal eye pattern by carrying out reading appearance one by one, and performing electrical signal processing.
[Claim 2]
In the data signal quality evaluation approach according to claim 1, the repeat frequency f1 of said sampling (Hz) fills f1=(n/m) f0**a (n and m are the natural number), and the range of Variable a,
[Equation 1]

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k,\ q\text{は自然数})$$

It comes out.
The data signal quality evaluation approach characterized by things.
[Claim 3]
In the data signal quality evaluation approach according to claim 2 when the exact value of a bit rate f0 (bit/s) is unknown The sweep of the value of f1 is carried out so that the repeat frequency f1 of said sampling (Hz) may fill f1=(n/m) f0**a (n and m are the natural number), and (n/m) 2q/{k+(n/m) q} f0 <=a< (n/m)2q/{k+(n/m) q-1} f0 (k is the natural number).
The data signal quality evaluation approach characterized by things.
[Claim 4]
The value of said variable a in the data signal quality evaluation approach according to claim 2 or 3,
[Equation 2]

$$a=\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

Come out, and it is and is in the direction of a time-axis to the order of measurement about sampling data. dt=1/(zf0)
counting from the first sampling data, laying a time amount location on top of every ik individual (i being the natural number), and displaying sampling data, when displaying by ********** -- a signal eye pattern -- asking -- data signal wave measurement and quality evaluation -- carrying out -- and
When the count of superposition is set to j (j is the natural number), ikj<=Nsamp is filled to the total number Nsamp of sampling data.
The data signal quality evaluation approach characterized by things.
[Claim 5]
the data signal quality evaluation approach according to claim 4 -- setting -- said variables i and k -- ikj<=Nsamp -- filling -- and
[Equation 3]

$$ijk \leqq \frac{kz}{2q(k-z)}$$

The data signal quality evaluation approach characterized by being a ******** value.
[Claim 6]
In the data signal quality evaluation approach according to claim 5 when the exact value of a bit rate f0 (bit/s) is unknown **a (n and m are the natural number), and (n/m) 2q/{k+(n/m) q} f0 <=a<(n/m)2q/{k+(n/m) q-1} f0 (k is the natural number) are filled. the repeat frequency f1 of said sampling (Hz) -- f1=(n/m) f0 -- The sweep of the value of k, the value of n/m, the value of q, and any one or more ** is carried out so that ikj<=Nsamp and ikj<=kz/{2q(k-z)} (i, j, and Nsamp are the natural number) may be filled.
The data signal quality evaluation approach characterized by things.
[Claim 7]
The value of said variable a in the data signal quality evaluation approach according to claim 2 or 3,
[Equation 4]

$$a=\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

Come out, and it is and is in the direction of a time-axis to the order of measurement about sampling data. dt=1/(zf0)
returning and laying a time amount location on top of every t=p/f0 (p being the natural number) 0, using the time amount location of the first sampling data as t= 0, and displaying sampling data, when displaying by ********** -- a signal eye pattern -- asking -- data signal wave measurement and quality evaluation -- carrying out -- and
When the count of superposition is set to j (j is the natural number), pkj<=Nsamp is filled to the total

number Nsamp of sampling data.
The data signal quality evaluation approach characterized by things.
[Claim 8]
In the data signal quality evaluation approach given in claims 4, 5, and 6 or any 1 term of 7 the sampling data of this Nsamp individual currently held at said buffer -- once -- or the process which carries out reading appearance one by one, performs electrical signal processing, and asks for a signal eye pattern -- a multiple-times repeat -- By piling up so that eye opening of each signal eye pattern may be in agreement in time, the total number of sampling data which constitutes a signal eye pattern is increased, and data signal wave measurement and quality evaluation are performed.
The data signal quality evaluation approach characterized by things.
[Claim 9]
The data signal quality evaluation approach characterized by making the amplitude histogram or time histogram called for from the sampling-data distribution which divides the signal eye pattern obtained in the direction on the strength or the direction of time amount, and is acquired in the data signal quality evaluation approach given in claims 2, 3, 4, 5, 6, and 7 or any 1 term of 8 into a data signal quality parameter.
[Claim 10]
The light of a bit rate f0 (bit/s) inputted or an electric data signal is a sampling pulse train generating means for it to be generated independently and to generate the light of the repeat frequency f1 (Hz) from which a bit rate f0 (bit/s) differs, or an electric sampling pulse train,
A data signal sampling means to sample this data signal of a bit rate f0 (bit/s) in this sampling pulse train, and to acquire a sampling signal,
An electrical-potential-difference maintenance means to change the light obtained by this data signal sampling means, or this electric sampling signal, and to memorize by two or more data as electric digital data,
the digital data currently held at this electrical-potential-difference maintenance means -- once -- or an electrical signal processing means to read one by one and to evaluate an optical data signal quality parameter in quest of a signal eye pattern,
A trigger signal generating means to give the trigger of data taking-in initiation and termination to this electrical-potential-difference maintenance means, and to give the trigger of data reading initiation and termination to this electrical signal processing means
Data signal quality evaluation equipment characterized by preparation ******.
[Claim 11]
In data signal quality evaluation equipment according to claim 10,
The repeat frequency f1 of said sampling (Hz) fills f1=(n/m) f0**a (n and m are the natural number), and the range of Variable a,
[Equation 5]

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k, q\text{は自然数})$$

It comes out.
Data signal quality evaluation equipment characterized by things.
[Claim 12]
In data signal quality evaluation equipment according to claim 11 this sampling pulse train generating means It has the function which makes adjustable the repeat frequency f1 of the sampling pulse train to generate (Hz). When the exact value of a bit rate f0 (bit/s) is unknown, so that f1=(n/m) f0**a (n and m are the natural number), and (n/m) 2q/{k+(n/m) q} f0 <=a<(n/m)2q/{k+(n/m) q-1} f0 (k is the natural number) may

be filled The sweep of the value of f1 is carried out.
Data signal quality evaluation equipment characterized by things.
[Claim 13]
In data signal quality evaluation equipment according to claim 11 or 12,
The value of said variable a
[Equation 6]

$$a=\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q}f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

Come out, and it is and is in the direction of a time-axis to the order of measurement about sampling data.
dt=1/(zf0)
counting from the first sampling data, laying a time amount location on top of every ik individual (i being the natural number), and displaying sampling data, when displaying by ********** -- a signal eye pattern -- asking -- data signal wave measurement and quality evaluation -- carrying out -- and
When the count of superposition is set to j (j is the natural number), ikj<=Nsamp is filled to the total number Nsamp of sampling data.
Data signal quality evaluation equipment characterized by things.
[Claim 14]
In data signal quality evaluation equipment according to claim 13,
said variables i and k -- ikj<=Nsamp -- filling -- and
[Equation 7]

$$ijk \leqq \frac{kz}{2q(k-z)}$$

It is a ******** value.
Data signal quality evaluation equipment characterized by things.
[Claim 15]
In data signal quality evaluation equipment according to claim 14 when the exact value of a bit rate f0 (bit/s) is unknown **a (n and m are the natural number), and (n/m) 2q/{k+(n/m) q} f0 <=a<(n/m)2q/{k+(n/m) q-1} f0 (k is the natural number) are filled. the repeat frequency f1 of said sampling (Hz) -- f1=(n/m) f0 -- In this electrical signal processing means, the sweep of the value of k, the value of n/m, the value of q, and any one or more ** is carried out so that ikj<=Nsamp and ikj<=kz/{2q(k-z)} (i, j, and Nsamp are the natural number) may be filled.
Data signal quality evaluation equipment characterized by things.
[Claim 16]
The value of said variable a in data signal quality evaluation equipment according to claim 11 or 12,
[Equation 8]

$$a=\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q}f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

Come out, and it is and is in the direction of a time-axis to the order of measurement about sampling data.
dt=1/(zf0)
returning and laying a time amount location on top of every t=p/f0 (p being the natural number) 0, using the time amount location of the first sampling data as t= 0, and displaying sampling data, when displaying by ********** -- a signal eye pattern -- asking -- data signal wave measurement and quality evaluation -- carrying out -- and
When the count of superposition is set to j (j is the natural number), pkj<=Nsamp is filled to the total number Nsamp of sampling data.
Data signal quality evaluation equipment characterized by things.
[Claim 17]
In data signal quality evaluation equipment given in claims 13, 14, and 15 or any 1 term of 16, the sampling data of this Nsamp individual currently held at said electrical-potential-difference maintenance means -- once -- or it has the eye opening assessment section which evaluates eye opening of a multiple-times repeat and each signal eye pattern for the process which carries out reading appearance one by one, and asks for a signal eye pattern in an electrical signal processing means, and the total number of sampling data which constitutes the signal eye pattern for perform data-signal wave measurement and quality evaluation from pile up so that this eye opening may are in agreement in time increases
Data signal quality evaluation equipment characterized by things.
[Claim 18]
In data signal quality evaluation equipment given in claims 11, 12, 13, 14, 15, and 16 or any 1 term of 17, Said electrical signal processing means is equipped with both or one side of the amplitude histogram assessment section which asks for an amplitude histogram as a data signal quality parameter, and the time histogram assessment section which asks for a time histogram as a data signal quality parameter,
This amplitude histogram and this time histogram are called for from the sampling-data distribution which divides a signal eye pattern in the amplitude direction and the direction of time amount, respectively, and is acquired.
Data signal quality evaluation equipment characterized by things.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]
This invention samples the data signal of the light which has a predetermined bit rate, or the electrical and electric equipment, in case it performs display of an eye pattern, and measurement of a signal quality, it is used, and it relates to the data signal quality evaluation approach and equipment by suitable high-speed sampling.
[0002]
[Description of the Prior Art]
The 1st example of conventional lightwave signal quality evaluation equipment is shown in drawing 10 (see nonpatent literature 1 and the nonpatent literature 2). This conventional lightwave signal quality evaluation equipment synchronizes with the clock with which the bit rate was extracted from a photo-electric-translation means 101 to change the lightwave signal of f0 (bit/s) into a modulating signal on the strength [electric], a clock extract means 102 to perform a clock extract from this modulating signal on the strength [electric], and this clock extract means 102. A repeat frequency has a sampling clock generating means 103 by which f1(Hz) (f1=(n/m) f0+a:n and m generate the natural number, and a generates the sampling clock of offset frequency), and the electrical signal processing means 104. This electrical signal processing means 104 samples the modulating signal on the strength [electric] inputted through the clock extract means 102 with this sampling clock, displays sampling-data distribution serially based on the sampling electrical signal acquired, and evaluates a lightwave signal quality parameter in quest of a signal eye pattern.
[0003]
As the 2nd example similar to the above-mentioned conventional example, there are an example of an optical sampling means by which f1(Hz) (f1=(n/m) f0+a:n and m used the natural number by offset frequency), and, as for a, the repeat frequency used the sampling light pulse train with pulse width sufficiently narrower than the time slot of a lightwave signal, and an example of the optical sampling means using a sampling clock (see the patent reference 1, the patent reference 2, and the nonpatent literature 3). These optical sampling means are arranged at the preceding paragraph of a photo-electric-translation means. A lightwave signal is branched with an optical branching means, and an optical sampling is performed using the sampling clock or sampling light pulse train which synchronized with the clock obtained by performing a clock extract from one output. A sampling lightwave signal is changed into a sampling electrical signal by the photo-electric-translation means. Sampling-data distribution is serially displayed based on a sampling electrical signal, and an electrical signal processing means estimates a lightwave signal quality parameter in quest of a signal eye pattern.
[0004]
[Patent reference 1]
The patent No. 2677372 official report
[Patent reference 2]
The patent No. 3239925 official report
[Patent reference 3]
The Europe patent application ****** EP 0920150A2 Number description

[Nonpatent literature 1]
"Handbook of ELECTRONIC TEST EQUIPMENT" (Section 5-8.SAMPLING OSCILLOSCOPE), pp.184-189, JOHN D.LENK, Prentice-Hall, Inc., Englewood Cliffs, and N.J., 1971
[Nonpatent literature 2]
"Modeling of the HP-1430 A Feedthrough Wide-Band (28-ps) Sampling Head", SEDKI M.RIAD, IEEE Transactions on Instrumentation and Measurement, Vol.IM-31, No.2, June 1982, pp.110-115
[Nonpatent literature 3]
"100 Gbit/s optical signal eye-diagram measurement with optical sampling using organic nonlinear optical crystal" and H.Takara, S.Kawanishi and A.Yokoo, S.Tomaru, T.Kitoh and M.Saruwatari, Electronics Letters, Vol.32, No.24.21st November 1996, pp.2256-2258
[Nonpatent literature 4]
"Optical signal quality monitoring method based on optical sampling", I.Shake, H.Takara, S.Kawanishi and Y.Yamabayashi, Electronics Letters, Vol.34, No.22, 29th October 1998, pp.2152-2154

[0005]

[Problem(s) to be Solved by the Invention]

the repeat frequency of the sampling clock in the conventional example 1 -- usually -- several 10- hundreds of kHz -- it is -- assessment -- the need -- since obtaining enough signal eye patterns took time amount and the wander of a lightwave signal became a problem, the clock extract was indispensable. Since electrical signal processing which searches for sampling-data distribution needed to be performed serially, the effectual sampling rate fell, obtaining enough signal eye patterns required for assessment took time amount and the wander of a lightwave signal became a problem in the example of the optical sampling using the sampling clock and sampling light pulse train in the conventional example 2 although the repeat frequency of this sampling clock or this sampling light pulse train was about 10MHz, the clock extract was indispensable.

[0006]

As mentioned above, since the whole of the 1st conventional example and the 2nd example needed a clock extract, buildup of equipment magnitude, complication of an approach or equipment, and buildup of equipment cost were problems. It considers as the 3rd conventional example (see the patent reference 3 and the nonpatent literature 4), and there is lightwave signal performance-monitoring equipment using an asynchronous sampling among the lightwave signal performance-monitoring equipment which does not need a clock extract. However, by the time it is applicable to degradation (a jitter, polarization distribution, etc.) of the direction of time amount, this approach will not have resulted, in order to evaluate the lightwave signal intensity distribution based on an asynchronous eye pattern.

[0007]

it be in offer the data signal quality evaluation approach and the equipment which the object enable the miniaturization of equipment magnitude , simplification of an approach or equipment , and the cutback of equipment cost by not need the clock extract section by having not made this invention in view of the above-mentioned point , and can supervise noise degradation or not only wavelength dispersion degradation but signal quality degradation of the directions of time amount , such as a jitter and polarization distribution degradation .

[0008]

[Means for Solving the Problem]

In order to attain the above-mentioned object, the data signal quality evaluation approach of this invention The light of a bit rate f0 (bit/s) inputted or an electric data signal is what is generated independently. The light of a different repeat frequency f1 (Hz) from a bit rate f0 (bit/s) or an electric sampling pulse train is used. The process which samples this data signal, changes the sampling signal of the light or the electrical and electric equipment obtained, and is held to a buffer as electric digital data N time (N is the natural number) after repeating the digital data of N individual currently held at said buffer -- once -- or by carrying out reading appearance one by one, and performing electrical signal processing, it is characterized by performing data signal wave measurement and quality evaluation in quest of a signal eye pattern.

[0009]

Moreover, the light of the bit rate f0 (bit/s) as which the data signal quality evaluation equipment of this invention is inputted, or an electric data signal is what is generated independently. A sampling pulse train generating means to generate the light of a different repeat frequency f1 (Hz) from a bit rate f0 (bit/s), or

an electric sampling pulse train, A data signal sampling means to sample this data signal of a bit rate f0 (bit/s) in this sampling pulse train, and to acquire a sampling signal, An electrical-potential-difference maintenance means to change the light obtained by this data signal sampling means, or this electric sampling signal, and to memorize by two or more data as electric digital data, At once the digital data currently held at this electrical-potential-difference maintenance means Or an electrical signal processing means to read one by one and to evaluate an optical data signal quality parameter in quest of a signal eye pattern, It is characterized by having a trigger signal generating means to give the trigger of data taking-in initiation and termination to this electrical-potential-difference maintenance means, and to give the trigger of data reading initiation and termination to this electrical signal processing means.

[0010]

[Embodiment of the Invention]

<The 1st operation gestalt>

The 1st operation gestalt of the data signal quality evaluation equipment by this invention is shown in drawing 1 . This depends on this invention according to claim 10. This operation gestalt is the case where the electrical signal electrical-and-electric-equipment sampling means 12 is used, as a data signal sampling means. In this case, the data signal to input is an electric data signal, and the sampling clock generating means 13 is used as a sampling pulse train generating means. Although drawing 1 shows the case where it inputs into the electrical signal electrical-and-electric-equipment sampling means 12 after changing the lightwave signal of a bit rate f0 (bit/s) into a modulating signal on the strength [electric] through the photo-electric-translation means 11 especially, when it inputs the electrical signal of a bit rate f0 (bit/s) into the electrical signal electrical-and-electric-equipment sampling means 12 as it is, the photo-electric-translation means 11 is unnecessary, and such an operation gestalt is also included in this operation gestalt. Actuation of this operation gestalt is explained below.

[0011]

The lightwave signal of a bit rate f0 (bit/s) results in the electrical signal electrical-and-electric-equipment sampling means 12 as a modulating signal on the strength [electric] through the photo-electric-translation means 11. On the other hand, repeat frequency f1(Hz) (f1=(n/m) f0+a or f1=(n/m) f0-a:n, and m are generated in the natural number, and a is generated for a sampling clock from the sampling clock generating means 13 in offset frequency). With this electrical signal electrical-and-electric-equipment sampling means 12, this modulating signal on the strength [electric] is sampled with this sampling clock, and a sampling electrical signal is acquired. With the electrical-potential-difference maintenance means 14, according to the trigger signal of the data taking-in initiation from the trigger signal generating means 15, analog-to-digital conversion (AD translation) of this sampling electrical signal is performed, and temporary storage maintenance actuation is performed. The electrical-potential-difference maintenance means 14 holds two or more sampling data until the trigger signal of data taking-in termination is sent from this trigger signal generating means 15. And it is outputted according to the trigger signal from the outside. Here, it can have electric buffer memory with the capacity for example, more than a kilobyte, and a high-speed AD translation circuit with the function of a MHz-GHz sampling etc. can be used. Moreover, the sampling gate width of face of this sampling clock has desirably good or less 1/4 extent of the time amount decided by the inverse number of the bit rate f0 of a lightwave signal.

[0012]

If the trigger signal of data reading initiation is sent towards the electrical signal processing means 16 from the trigger signal generating means 15 after performing fixed time data taking in and holding two or more sampling data in the electrical-potential-difference maintenance means 14 This electrical signal processing means 16 responds to the trigger signal of this data reading initiation. Read two or more sampling data from this electrical-potential-difference maintenance means 14, and it asks for a signal eye pattern from these sampling data. It is displayed, or and it outputs to a predetermined external device so that predetermined data processing concerning signal quality degradation of the directions of time amount, such as noise degradation, wavelength dispersion degradation, and a jitter, polarization distribution degradation, etc. may be performed and a lightwave signal quality parameter can be evaluated. [display]

[0013]

Here, the repeat frequency f1 of a sampling clock is only determined based on f0 which is a number related to the lightwave signal bit rate f0 (n/m), and does not perform following in footsteps of the bit phase of a lightwave signal using a clock extract etc. For example, a lightwave signal bit rate considers the case where

they are 2.5 Gbit/s, 10 Gbit/s, or 40 Gbit/s. In this case, if it considers as information required in order to determine the repeat frequency of a sampling clock, for example, 100MHz which is one of the common divisors of those bit rates is in a solution, f1 can be determined based on it. For example, if the repeat frequency of a sampling clock is set up by (100 MHz+aHz) and 15000 points are assumed as the required number of sampling data, data taking-in time amount will be set to about 150 microseconds. That is, by this approach, only change in less than about 150 microseconds influences the eye pattern used for assessment among the bit phase shifts by the wander. When the temperature gradient of a day considers as 60 degrees C (12 hours), the temperature change in 150 microseconds is about 2.1x10 to 7 degree C. If it takes into consideration that the amount of pulse delay in the quartz fiber of nylon coating which forms the transmission line of a lightwave signal is maximum about 0.2ps/m/degree C (actual measurement), the amount of pulse delay produced when the temperature of the 100km whole transmission line changes with atmospheric temperature fluctuation will serve as 4.2x10-3ps among 150 microseconds. this -- resolution -- as well as the electric sampling of 20ps extent, since it is the value which can also disregard the lightwave signal light sampling of 1ps extent, the eye pattern by this approach can be evaluated as a synchronous eye pattern in false.

[0014]

in addition -- as the range of the offset frequency a -- for example

[Equation 9]

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k,\ q\text{は自然数})$$

It sets up so that it may become.

[0015]

Here, n/m and the semantics which k and q express are explained in full detail for the below-mentioned <example of a display of the eye pattern in the gestalt of each operation>.

Moreover, the input signal (data signal) in the data signal quality evaluation equipment of this invention may not be limited to the lightwave signal of the bit rate f0 (bit/s) which was mentioned above, but may be an electrical signal of a bit rate f0 (bit/s). What is necessary is to omit the photo-electric-translation means 11 and just to input the input electrical signal of a bit rate f0 into the electrical signal electrical-and-electric-equipment sampling means 12 directly with the gestalt of operation shown in drawing 1 in that case.

[0016]

Moreover, I hear that not making the repeat frequency f1 of a sampling clock follow in footsteps of the bit phase of a lightwave signal (or electrical signal) using a clock extract etc. generates the sampling signal of a frequency f1 (Hz) repeatedly independently of a data signal, and there is. "Independence" means that the tracking of the bit phase relation between a data signal and a sampling signal always is not carried out here.

[0017]

moreover, the reading appearance of two or more sampling data from the electrical-potential-difference maintenance means 14 by the electrical signal processing means 16 -- carrying out -- you may make it read two or more sampling data at once, and may make it read them one by one

[0018]

<The 2nd operation gestalt>

The 2nd operation gestalt of the data signal quality evaluation equipment of this invention is shown in drawing 2 . This depends on this invention according to claim 10. This operation gestalt is the case where the lightwave signal electrical-and-electric-equipment sampling means 22 is used, as a data signal sampling means. In this case, the data signal to input is a data signal of light, and the sampling clock generating

means 23 is used as a sampling pulse train generating means. In this case, since the sampling signal (sampling lightwave signal) of light is acquired by the lightwave signal electrical-and-electric-equipment sampling means 22, in order to change this sampling signal into electric digital data and to hold it, after performing photo electric translation, the procedure of performing analog-to-digital conversion is required. Therefore, in drawing 2 , it has composition using the electrical-potential-difference maintenance means 14 with a analog-to-digital conversion function after the photo-electric-translation means 21. The same reference mark is attached to the same configuration as drawing 1 in drawing 2 . Actuation of this operation gestalt is explained below.

[0019]

The lightwave signal of a bit rate f0 (bit/s) results in the lightwave signal electrical-and-electric-equipment sampling means 22. On the other hand, repeat frequency f1(Hz) (f1=(n/m) f0+a or f1=(n/m) f0-a:n, and m are generated in the natural number, a is generated from the sampling clock generating means 23 in offset frequency), and a sampling clock results in this lightwave signal electrical-and-electric-equipment sampling means 22. Here, electric short pulse generating by the combination of a synthesized signal generator and a comb generator etc. can be used for the sampling clock generating means 23. As for the repeat frequency f1 of this sampling clock, it is desirable that it is the high speed of MHz-GHz extent here. Moreover, the band of this comb generator is extended to about 4 times of the bit rate f0 of a lightwave signal, and it is desirable to determine the pulse width of this electric short pulse as time amount width-of-face extent called for with the Fourier transform of the band of this comb generator. Moreover, electric amplifier can also be used for the preceding paragraph or the latter part of this comb generator if needed. Moreover, a baseband clipper can also be used for the latter part of this comb generator if needed.

[0020]

With this lightwave signal electrical-and-electric-equipment sampling means 22, this lightwave signal is sampled with this sampling clock, and the sampling lightwave signal of a bit rate f1 is acquired. The gate actuation by the electroabsorption modulator etc. can be used for this lightwave signal electrical-and-electric-equipment sampling means 22. The transparency band of the lightwave signal of this lightwave signal electrical-and-electric-equipment sampling means 22 is good in it being about lightwave signal bit rate f0 desirably here. Moreover, the sampling gate width of face of this lightwave signal electrical-and-electric-equipment sampling means 22 has desirably good or less 1/4 extent of the time amount decided by the inverse number of the bit rate f0 of a lightwave signal. This sampling lightwave signal is changed into a sampling electrical signal by the photo-electric-translation means 21.

[0021]

With the electrical-potential-difference maintenance means 14, according to the trigger signal of the data taking-in initiation from the trigger signal generating means 15, analog-to-digital conversion (AD translation) of this sampling electrical signal is performed, and temporary storage maintenance actuation is performed. And this electrical-potential-difference maintenance means 14 holds two or more sampling data until the trigger signal of data taking-in termination is sent from this trigger signal generating means 15, and outputs it according to the trigger signal from the outside. Here, it can have electric buffer memory with the capacity for example, more than a kilobyte, and a high-speed AD translation circuit with the function of a MHz-GHz sampling etc. can be used. In this electrical-potential-difference maintenance means 14, if the trigger signal of data reading initiation is sent towards the electrical signal processing means 16 from the trigger signal generating means 15 after performing fixed time data taking in and holding two or more sampling data, according to the trigger signal of nucleus data reading initiation, this electrical signal processing means 16 will read two or more sampling data from this electrical-potential-difference maintenance means 14, and will evaluate a lightwave signal quality parameter in quest of a signal eye pattern from these sampling data.

[0022]

<The 3rd operation gestalt>

The 3rd operation gestalt of the data signal quality evaluation equipment of this invention is shown in drawing 3 . This depends on this invention according to claim 10. This operation gestalt is the case where the lightwave signal light sampling means 32 is used, as a data signal sampling means. In this case, the data signal to input is a data signal of light, and the sampling light pulse train generating means 33 is used as a sampling pulse train generating means. In this case, since the sampling signal (sampling lightwave signal) of light is acquired by the lightwave signal light sampling means 32, in order to change this sampling signal into

electric digital data and to hold it, after performing photo electric translation, the procedure of performing analog-to-digital conversion is required. Therefore, in drawing 3 , it has composition using the electrical-potential-difference maintenance means 14 with a analog-to-digital conversion function after the photo-electric-translation means 21. The same reference mark is attached to the same configuration as what is shown in drawing 1 or drawing 2 in drawing 3 . Actuation of this operation gestalt is explained below.

[0023]

The lightwave signal of a bit rate f0 (bit/s) results in the lightwave signal light sampling means 32. On the other hand, repeat frequency f1(Hz) (f1=(n/m) f0+a or f1=(n/m) f0-a:n, and m are generated in the natural number, a is generated from the sampling light pulse train generating means 33 in offset frequency), and a sampling light pulse train results in this lightwave signal light sampling means 32. This sampling light pulse train has pulse width sufficiently narrower than the time amount decided by the inverse number of the bit rate f0 of a lightwave signal here. The laser diode of a gain switch mold, fiber ring laser, a mode locking laser diode, etc. can be used for this sampling light pulse train generating means 33. As for the repeat frequency f1 of this sampling light pulse train, it is desirable that it is the high speed of MHz-GHz extent here. Moreover, as for the pulse width of this sampling light pulse train, about [of the time amount decided by the inverse number of the bit rate f0 of ****** / 1/4 or less] is desirable.

[0024]

With this lightwave signal light sampling means 32, this lightwave signal is sampled in this sampling light pulse train, and a sampling lightwave signal is acquired. Here, the nonlinear optical effect between a lightwave signal and a sampling light pulse train can be used for the lightwave signal light sampling means 32, and nonlinear optics media, such as KTP (KTiOPO4), AANP (2-adamantylamino-5-nitropyridine), and PPLN (Periodically Poled Lithium Niobate), can be used for it. Moreover, as a nonlinear optical effect, SFG (sum cycle light generating), SHG (second harmonic generation), FWM (4 light-wave mixing), etc. can be used.

[0025]

This sampling lightwave signal is changed into a sampling electrical signal by the photo-electric-translation means 21. With the electrical-potential-difference maintenance means 14, according to the trigger signal of the data taking-in initiation from the trigger signal generating means 15, analog-to-digital conversion (AD translation) of this sampling electrical signal is performed, and temporary storage maintenance actuation is performed. Two or more sampling data until the trigger signal of data taking-in termination is sent from this trigger signal generating means 15 are held. And it is outputted according to the trigger signal from the outside. Here, it can have electric buffer memory with the capacity for example, more than a kilobyte, and a high-speed AD translation circuit with the function of a MHz-GHz sampling etc. can be used. In this electrical-potential-difference maintenance means 14, if the trigger signal of data reading initiation is sent towards the electrical signal processing means 16 from the trigger signal generating means 15 after performing fixed time data taking in and holding two or more sampling data, according to the trigger signal of this data reading initiation, this electrical signal processing means 16 will read two or more sampling data from this electrical-potential-difference maintenance means 14, and will evaluate a lightwave signal quality parameter in quest of a signal eye pattern from these sampling data.

[0026]

<The 4th operation gestalt>

This operation gestalt describes the example of an assessment procedure in case the exact value of the signal bit rate f0 is not known. First, if it is SDH when the signal format is known for example, it will be thought that a signal bit rate is either of ... 39.81312 Gbit/s 9.95328 Gbit/s 2.48832 Gbit/s. However, a actual signal bit rate can consider that only df (Hz) has shifted to accuracy, for example, permits df=**200ppm in SDH. A gap of only the part as which it will not consider df to f1, either, if only df determines the repeat frequency of a sampling clock based on the common divisor of 2.48832 Gbit/s, 9.95328 Gbit/s, and 39.81312 Gbit/s etc., without taking df into consideration noting that the signal bit rate has shifted actually arises. The f1 that what is necessary is just to fill f1=(n/m) f0**a (for n and m to be the natural number), and (n/m) 2q/{k+(n/m) q} f0 <=a<(n/m)2q/{k+(n/m) q-1} f0 (for k to be the natural number) So that it may carry out the sweep of the value of f1 or ikj<=Nsamp and ikj<=kz/{2q(k-z)} (i, j, and Nsamp are the natural number) may be filled, when not filling Measurement of the open eye pattern is enabled by carrying out the sweep of the value of f1, the value of k, the value of n/m, the value of q, and any one or more **. In addition, the semantics which n/m, and k, q and z express is explained in full detail

in <the example of a display of the eye pattern in the gestalt of each operation> mentioned later. And the approach of carrying out the sweep of these parameters can be applied not only when a signal format shows a signal bit rate to some extent, but when a signal bit rate is not known at all. However, the demand to the adjustable width of face of f1 becomes large in that case.
The conditions which enable eye pattern measurement without the sweep of f1,
f1 >=(2, f0, Nsamp, and|df|) 1/2
By coming out, being, for example, in the case of f0=9.95328 Gbit/s, df=200ppm, and Nsamp=250, becoming f1>=1GHz order, and making a sampling rate into a high speed, even when a signal bit rate cannot be known to accuracy, eye pattern measurement is attained.
[0027]
<The example of quality evaluation by each operation gestalt>
With reference to drawing 4 thru/or drawing 8 , the example of quality evaluation by the 1st of this invention thru/or the 4th operation gestalt is explained. The typical example of a synchronous eye pattern and the example of an assessment parameter are shown.
[0028]
Drawing 4 is the example of the eye pattern of an NRZ signal (Non-Return-to-Zero signal). The amplitude histogram when setting up the time window of dt focusing on the time amount from which eye opening of the direction on the strength serves as max is shown, and the averages mu1 and mu0 and standard deviation sigma1 and sigma0 are evaluated about a mark and each distribution of a tooth space.
[0029]
moreover
Q=|mu1-mu0|/sigma1+sigma0
Q value come out of and calculated can also be made into an assessment parameter. Here, |mu1-mu0| expresses the absolute value of the difference of the averages mu1 and mu0.
[0030]
From Q value,
BER=erfc(Q)
A ******** bit error rate can be estimated. Here, BER expresses a bit error rate (Bit Error Rate), and erfc expresses an error complementary function.
[0031]
Drawing 5 is the example of the eye pattern of RZ signal (Return to zero signal). The method of assessment of the averages mu1 and mu0, standard deviation sigma1 and sigma0, and Q value is the same as that of the case of NRZ mentioned above.
[0032]
Drawing 6 is the example of the eye pattern of an NRZ signal. The amplitude histogram when setting up the cross point of an eye pattern for the time window of dt as a core is shown, and the averages mu1 and mu0 and mucross are evaluated about a mark, distribution of a tooth space, and the frequency distribution near a cross point, respectively.
[0033]
here -- for example
Rcross=|mu cross-mu 0|/|mu1-mu0|
The gap of the amplitude reinforcement of a ** cross point is shown, and it becomes the parameter by which the effect of the pulse breadth by wavelength dispersion etc. is evaluated.
[0034]
Drawing 7 is the example of the eye pattern of an NRZ signal. The time histogram of the part surrounded by the time amount width of face dt and the width of face dI on the strength is shown, and standard deviation sigmat is evaluated. sigmat becomes the parameter by which the effect of a jitter is evaluated.
[0035]
Drawing 8 is the example of the eye pattern of RZ signal. Drawing of a left part shows the amplitude histogram when setting up the time window of dta focusing on the time amount from which eye opening of the direction on the strength serves as max, and is evaluating the averages mu1 and mu0 about a mark and each distribution of a tooth space. Upside drawing shows the time histogram of the part surrounded by the width of face dI on the strength and the time amount width of face dt of |mu1-mu0|/2 centering on a value, and is evaluating the difference TFWHM of standard deviation sigmat and the average. sigmat becomes the

parameter by which the effect of a jitter is evaluated. TFWHM shows the full width at half maximum of RZ pulse, and serves as a parameter by which the pulse breadth by wavelength dispersion etc. is evaluated.
[0036]
In addition, assessment of degradation according to PMD (polarization mode dispersion) by setting the window of the time amount width of face dt and the frequency width of face dI as arbitration etc. is possible.
[0037]
<The example of a display of the eye pattern in the gestalt of each operation>
About a display, it can display on a display as it is at the order which sampled two or more sampling data, for example. In this case, no points can necessarily be arranged in time series, but overwrite can be carried out from the place of time amount zero once again a certain period. An eye pattern can be displayed by repeating it about all sampling points.
[0038]
Hereafter, the period which carries out overwrite is explained. Here, it is a, when the bit rate of a data signal is expressed with f0 (bit/s) and the repeat frequency f1 of a sampling (Hz) is expressed with f1=(n/m) f0+a or f1=(n/m) f0−a (the natural number and a are an offset frequency for n and m),
[Equation 10]

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k,\ q\text{は自然数})$$

The case where ****** is filled is explained.
It is a value related to the ratio of f0 and f1, for example, n/m is 1/100, and n/m is f0 here. When it is 10 (Gbit/s), f1 is set to about 100 (MHz), and a sampling point expresses that it is the sampling frequency which is extent obtained one point to about 100 bits of a data signal. Moreover, k is a value related to the period which carries out overwrite, and means carrying out overwrite k sampling point numbers at a time. Moreover, q is a value showing a part for what bit of a data signal is reproduced, when k sampling points are arranged in time series. Below, the example of a plot of the points P1−P8 corresponding to each sampling data is explained with reference to drawing 9 (a) − (d) about the case of f1=(n/m)−a as an example. Drawing 9 (a) is drawing (however drawing 9 (a) only the points P1−P5 graphic display) showing a data signal wave, and drawing 9 (b) − (d) is drawing showing the example of a plot. Moreover, each variable shall fill n/m=1, k= 4, and q= 1.
[0039]
In the above-mentioned case, the offset frequency a (=** (f1−f0)) serves as a value of the range of f(1/5) 0 <=a<(1/4) f0. That is, it is 1/4/f0 <=1/f1−1/f0<1/3/f0, and I hear that deltat (=1−/f1−1/f0) is set up smaller [it is larger than one fourth of one time slots which are the inverse number of f0, and] than one third, and there is. Points P1−P4 can reproduce the wave in 1 time slot by arranging in order (drawing 9 (b)).
[0040]
And in this example, a point P5 shall not be plotted following a point P4, but shall be returned and plotted to time amount zero. Here, there are two kinds of methods of superposition.
[0041]
(1) The 1st method of superposition is doubling the time amount location of a point P5 with the time amount location of a point P1, as shown in drawing 9 (c). If the time amount location of a point P5 is doubled with a point P1, the wave of the 2nd superposition will become the thing [wave / 1st] shifted somewhat in time. If it piles up like the 3rd time and the 4th time, since a gap will become large and will go little by little, when the count of superposition increases, the eye will close gradually. Information required to realize this superposition is only the value of n/m. Since a sampling clock can be set up locally, k is

decided to be arbitration in the range of the natural number, and the period of overwrite is decided according to it. Although k is the natural number, if the wave is complicated, the larger one can tell a wave-like rendering that it is desirable.

[0042]

(2) The 2nd method of superposition is doubling the time amount location of a point P5 on the basis of the integral multiple of 1/f0, as shown in drawing 9 (d). If the time amount location of a point P5 is doubled on the basis of the integral multiple of 1/f0, the wave of the 2nd superposition will become what lapped with the 1st wave. Instead, it is necessary to get to know the absolute value of f0.

[0043]

Now, in the approach of (1), the gap when doubling the time amount location of a point P5 similarly to a point P1 is estimated. If it is a=(1/4) f0, since a point P5 is in agreement with a point P1 with the period of 1/f0, if it is that which carries out overwrite four points at a time (or overwrite is carried out by the multiple of 4), even if it will continue to infinity, a beautiful eye pattern is obtained. However, as shown in the formula which appoints the range of the above-mentioned a in this case, a has shifted from f(1/4) 0 for a while.

[0044]

If z is made into the real number which fills k-1<z<=k here,

[Equation 11]

$$a=\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q}f_0$$

It comes out, it is, and since it is n/m=1 and q= 1 in now, it is set to a={1/(z+1)} f0 considering z as the real number which fills 3< z<4. When it calculates using this, compared with the case of a=(1/4) f0, gap deltaT produced when piling up the wave is deltaT=(4-z)/(zf0). That is, generally, when the period of superposition is set to ik (i is i= 1 at the natural number and an example), it becomes deltaT=q(k-z) i/(zf0). conversely, if it says, it will pile up with 2 times and 3 times -- ** -- it will be said that it is written while it is alike and shifting in the direction of deltaT [every] time amount. Since an eye pattern will be thoroughly closed if accumulation of the gap becomes half [of one time slot of the inverse number of f0], it serves as an upper limit of a gap. It is ikj<=Nsamp, when the number of sampling points measured at once is set to Nsamp and the count of overwrite is set to j. Therefore, when accumulated of a gap is set to Sum [deltaT], Sum [deltaT] is,

[Equation 12]

$$Sum[\Delta T]=\frac{q(k-z)ij}{zf_0}$$

It becomes.

[0045]

Since that this becomes below one half of 1/f0 are the conditions which enable eye opening assessment,

[Equation 13]

$$\frac{(k-z)ijq}{zf_0}\leq\frac{1}{2f_0}$$

It is got blocked.
[Equation 14]

$$ikj \leqq \frac{zk}{2q(k-z)}$$

In the range of the number of ******** sampling points, even if it uses a local clock, it will be said that eye opening can be evaluated.
[0046]
That is, the value of a
[Equation 15]

$$\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q} f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

When coming out, and it is and the sampling data of a Nsamp individual are displayed in the direction of a time-axis with a dt=1/(zf0) time interval in order of measurement When data signal wave measurement and quality evaluation are performed in quest of a signal eye pattern by returning and laying a time amount location on top of every t=p/f0 (p being the natural number) 0, using the time amount location of the first sampling data as t= 0, and displaying sampling data, When the count of superposition is set to j (j is the natural number), data signal quality evaluation can be performed by filling pkj<=Nsamp to the total number Nsamp of sampling data.
[0047]
If it is furthermore developed, it repeats performing data taking in of Nsamp and an eye pattern display as mentioned above j times, and after piling up j eye patterns on the basis of the maximum point of each eye opening, it can evaluate. If it carries out like this, the number of sampling points effectually used for assessment can be increased, and the indeterminacy of assessment can be reduced more.
[0048]
[Effect of the Invention]
Since the clock extract section is not needed as explained above, according to this invention, the miniaturization of equipment magnitude, In spite of not using a synchronous means by becoming reducible [simplification of an approach or equipment, and equipment cost], and performing high-speed sampling and data taking in using a buffer The false synchronous lightwave signal eye pattern which lost the effect of a wander can be obtained, and the data signal quality evaluation approach and equipment which can supervise noise degradation or not only wavelength dispersion degradation but signal quality degradation of the directions of time amount, such as a jitter and polarization distribution degradation, can be offered.
[0049]
Moreover, in this invention, a lightwave signal bit rate applicable compared with the approach using an electric sampling by using the optical sampling method becomes wide range.
[Brief Description of the Drawings]
[Drawing 1] It is the block diagram showing the configuration of the 1st of the gestalt of operation of this invention.
[Drawing 2] It is the block diagram showing the configuration of the 2nd of the gestalt of operation of this invention.
[Drawing 3] It is the block diagram showing the configuration of the 3rd of the gestalt of operation of this

invention.
[Drawing 4] It is drawing for explaining an example of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 5] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 6] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 7] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 8] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 9] It is drawing for explaining the example of a data plot by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 10] It is the block diagram showing the configuration of the conventional example.
[Description of Notations]
11 Photo-Electric-Translation Means
12 Electrical Signal Electrical-and-Electric-Equipment Sampling Means
13 Sampling Clock Generating Means
14 Electrical-Potential-Difference Maintenance Means
15 Trigger Signal Generating Means
16 Electrical Signal Processing Means
21 Photo-Electric-Translation Means
22 Lightwave Signal Electrical-and-Electric-Equipment Sampling Means
23 Sampling Clock Generating Means
32 Lightwave Signal Light Sampling Means
33 Sampling Light Pulse Train Generating Means

[Translation done.]

TECHNICAL FIELD

[Field of the Invention]
This invention samples the data signal of the light which has a predetermined bit rate, or the electrical and electric equipment, in case it performs display of an eye pattern, and measurement of a signal quality, it is used, and it relates to the data signal quality evaluation approach and equipment by suitable high-speed sampling.
[0002]

[Translation done.]

PRIOR ART

[Description of the Prior Art]
The 1st example of conventional lightwave signal quality evaluation equipment is shown in drawing 10 (see nonpatent literature 1 and the nonpatent literature 2). This conventional lightwave signal quality evaluation equipment synchronizes with the clock with which the bit rate was extracted from a photo-electric-translation means 101 to change the lightwave signal of f0 (bit/s) into a modulating signal on the strength [electric], a clock extract means 102 to perform a clock extract from this modulating signal on the strength [electric], and this clock extract means 102. A repeat frequency has a sampling clock generating means 103 by which f1(Hz) (f1=(n/m) f0+a:n and m generate the natural number, and a generates the sampling clock of offset frequency), and the electrical signal processing means 104. This electrical signal processing means 104 samples the modulating signal on the strength [electric] inputted through the clock extract means 102 with this sampling clock, displays sampling-data distribution serially based on the sampling electrical signal acquired, and evaluates a lightwave signal quality parameter in quest of a signal eye pattern.
[0003]
As the 2nd example similar to the above-mentioned conventional example, there are an example of an optical sampling means by which f1(Hz) (f1=(n/m) f0+a:n and m used the natural number by offset frequency), and, as for a, the repeat frequency used the sampling light pulse train with pulse width sufficiently narrower than the time slot of a lightwave signal, and an example of the optical sampling means using a sampling clock (see the patent reference 1, the patent reference 2, and the nonpatent literature 3). These optical sampling means are arranged at the preceding paragraph of a photo-electric-translation means. A lightwave signal is branched with an optical branching means, and an optical sampling is performed using the sampling clock or sampling light pulse train which synchronized with the clock obtained by performing a clock extract from one output. A sampling lightwave signal is changed into a sampling electrical signal by the photo-electric-translation means. Sampling-data distribution is serially displayed based on a sampling electrical signal, and an electrical signal processing means estimates a lightwave signal quality parameter in quest of a signal eye pattern.
[0004]
[Patent reference 1]
The patent No. 2677372 official report
[Patent reference 2]
The patent No. 3239925 official report
[Patent reference 3]
The Europe patent application ****** EP 0920150A2 Number description
[Nonpatent literature 1]
"Handbook of ELECTRONIC TEST EQUIPMENT" (Section 5-8.SAMPLING OSCILLOSCOPE), pp.184-189, JOHN D.LENK, Prentice-Hall, Inc., Englewood Cliffs, and N.J., 1971
[Nonpatent literature 2]
"Modeling of the HP-1430 A Feedthrough Wide-Band (28-ps) Sampling Head", SEDKI M.RIAD, IEEE Transactions on Instrumentation and Measurement, Vol.IM-31, No.2, June 1982, pp.110-115
[Nonpatent literature 3]
"100 Gbit/s optical signal eye-diagram measurement with optical sampling using organic nonlinear optical

crystal" and H.Takara, S.Kawanishi and A.Yokoo, S.Tomaru, T.Kitoh and M.Saruwatari, Electronics Letters, Vol.32, No.24.21st November 1996, pp.2256-2258
[Nonpatent literature 4]
"Optical signal quality monitoring method based on optical sampling", I.Shake, H.Takara, S.Kawanishi and Y.Yamabayashi, Electronics Letters, Vol.34, No.22, 29th October 1998, pp.2152-2154
[0005]

[Translation done.]

EFFECT OF THE INVENTION

[Effect of the Invention]
Since the clock extract section is not needed as explained above, according to this invention, the miniaturization of equipment magnitude, In spite of not using a synchronous means by becoming reducible [simplification of an approach or equipment, and equipment cost], and performing high-speed sampling and data taking in using a buffer The false synchronous lightwave signal eye pattern which lost the effect of a wander can be obtained, and the data signal quality evaluation approach and equipment which can supervise noise degradation or not only wavelength dispersion degradation but signal quality degradation of the directions of time amount, such as a jitter and polarization distribution degradation, can be offered.
[0049]
Moreover, in this invention, a lightwave signal bit rate applicable compared with the approach using an electric sampling by using the optical sampling method becomes wide range.

[Translation done.]

TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention]
the repeat frequency of the sampling clock in the conventional example 1 -- usually -- several 10-hundreds of kHz -- it is -- assessment -- the need -- since obtaining enough signal eye patterns took time amount and the wander of a lightwave signal became a problem, the clock extract was indispensable. Since electrical signal processing which searches for sampling-data distribution needed to be performed serially, the effectual sampling rate fell, obtaining enough signal eye patterns required for assessment took time amount and the wander of a lightwave signal became a problem in the example of the optical sampling using the sampling clock and sampling light pulse train in the conventional example 2 although the repeat frequency of this sampling clock or this sampling light pulse train was about 10MHz, the clock extract was indispensable.
[0006]
As mentioned above, since the whole of the 1st conventional example and the 2nd example needed a clock extract, buildup of equipment magnitude, complication of an approach or equipment, and buildup of equipment cost were problems. It considers as the 3rd conventional example (see the patent reference 3 and the nonpatent literature 4), and there is lightwave signal performance-monitoring equipment using an asynchronous sampling among the lightwave signal performance-monitoring equipment which does not need a clock extract. However, by the time it is applicable to degradation (a jitter, polarization distribution, etc.) of the direction of time amount, this approach will not have resulted, in order to evaluate the lightwave signal intensity distribution based on an asynchronous eye pattern.
[0007]
it be in offer the data signal quality evaluation approach and the equipment which the object enable the miniaturization of equipment magnitude , simplification of an approach or equipment , and the cutback of equipment cost by not need the clock extract section by having not made this invention in view of the above-mentioned point , and can supervise noise degradation or not only wavelength dispersion degradation but signal quality degradation of the directions of time amount , such as a jitter and polarization distribution degradation .
[0008]

[Translation done.]

MEANS

[Means for Solving the Problem]
In order to attain the above-mentioned object, the data signal quality evaluation approach of this invention The light of a bit rate f0 (bit/s) inputted or an electric data signal is what is generated independently. The light of a different repeat frequency f1 (Hz) from a bit rate f0 (bit/s) or an electric sampling pulse train is used. The process which samples this data signal, changes the sampling signal of the light or the electrical and electric equipment obtained, and is held to a buffer as electric digital data N time (N is the natural number) after repeating the digital data of N individual currently held at said buffer -- once -- or by carrying out reading appearance one by one, and performing electrical signal processing, it is characterized by performing data signal wave measurement and quality evaluation in quest of a signal eye pattern.
[0009]
Moreover, the light of the bit rate f0 (bit/s) as which the data signal quality evaluation equipment of this invention is inputted, or an electric data signal is what is generated independently. A sampling pulse train generating means to generate the light of a different repeat frequency f1 (Hz) from a bit rate f0 (bit/s), or an electric sampling pulse train, A data signal sampling means to sample this data signal of a bit rate f0 (bit/s) in this sampling pulse train, and to acquire a sampling signal, An electrical-potential-difference maintenance means to change the light obtained by this data signal sampling means, or this electric sampling signal, and to memorize by two or more data as electric digital data, At once the digital data currently held at this electrical-potential-difference maintenance means Or an electrical signal processing means to read one by one and to evaluate an optical data signal quality parameter in quest of a signal eye pattern, It is characterized by having a trigger signal generating means to give the trigger of data taking-in initiation and termination to this electrical-potential-difference maintenance means, and to give the trigger of data reading initiation and termination to this electrical signal processing means.
[0010]
[Embodiment of the Invention]
<The 1st operation gestalt>
The 1st operation gestalt of the data signal quality evaluation equipment by this invention is shown in drawing 1 . This depends on this invention according to claim 10. This operation gestalt is the case where the electrical signal electrical-and-electric-equipment sampling means 12 is used, as a data signal sampling means. In this case, the data signal to input is an electric data signal, and the sampling clock generating means 13 is used as a sampling pulse train generating means. Although drawing 1 shows the case where it inputs into the electrical signal electrical-and-electric-equipment sampling means 12 after changing the lightwave signal of a bit rate f0 (bit/s) into a modulating signal on the strength [electric] through the photo-electric-translation means 11 especially, when it inputs the electrical signal of a bit rate f0 (bit/s) into the electrical signal electrical-and-electric-equipment sampling means 12 as it is, the photo-electric-translation means 11 is unnecessary, and such an operation gestalt is also included in this operation gestalt. Actuation of this operation gestalt is explained below.
[0011]
The lightwave signal of a bit rate f0 (bit/s) results in the electrical signal electrical-and-electric-equipment sampling means 12 as a modulating signal on the strength [electric] through the photo-electric-translation means 11. On the other hand, repeat frequency f1(Hz) (f1=(n/m) f0+a or f1=(n/m) f0-a:n, and m are generated in the natural number, and a is generated for a sampling clock from the sampling clock

generating means 13 in offset frequency). With this electrical signal electrical-and-electric-equipment sampling means 12, this modulating signal on the strength [electric] is sampled with this sampling clock, and a sampling electrical signal is acquired. With the electrical-potential-difference maintenance means 14, according to the trigger signal of the data taking-in initiation from the trigger signal generating means 15, analog-to-digital conversion (AD translation) of this sampling electrical signal is performed, and temporary storage maintenance actuation is performed. The electrical-potential-difference maintenance means 14 holds two or more sampling data until the trigger signal of data taking-in termination is sent from this trigger signal generating means 15. And it is outputted according to the trigger signal from the outside. Here, it can have electric buffer memory with the capacity for example, more than a kilobyte, and a high-speed AD translation circuit with the function of a MHz-GHz sampling etc. can be used. Moreover, the sampling gate width of face of this sampling clock has desirably good or less 1/4 extent of the time amount decided by the inverse number of the bit rate f0 of a lightwave signal.

[0012]

If the trigger signal of data reading initiation is sent towards the electrical signal processing means 16 from the trigger signal generating means 15 after performing fixed time data taking in and holding two or more sampling data in the electrical-potential-difference maintenance means 14 This electrical signal processing means 16 responds to the trigger signal of this data reading initiation. Read two or more sampling data from this electrical-potential-difference maintenance means 14, and it asks for a signal eye pattern from these sampling data. It is displayed, or and it outputs to a predetermined external device so that predetermined data processing concerning signal quality degradation of the directions of time amount, such as noise degradation, wavelength dispersion degradation, and a jitter, polarization distribution degradation, etc. may be performed and a lightwave signal quality parameter can be evaluated. [display]

[0013]

Here, the repeat frequency f1 of a sampling clock is only determined based on f0 which is a number related to the lightwave signal bit rate f0 (n/m), and does not perform following in footsteps of the bit phase of a lightwave signal using a clock extract etc. For example, a lightwave signal bit rate considers the case where they are 2.5 Gbit/s, 10 Gbit/s, or 40 Gbit/s. In this case, if it considers as information required in order to determine the repeat frequency of a sampling clock, for example, 100MHz which is one of the common divisors of those bit rates is in a solution, f1 can be determined based on it. For example, if the repeat frequency of a sampling clock is set up by (100 MHz+aHz) and 15000 points are assumed as the required number of sampling data, data taking-in time amount will be set to about 150 microseconds. That is, by this approach, only change in less than about 150 microseconds influences the eye pattern used for assessment among the bit phase shifts by the wander. When the temperature gradient of a day considers as 60 degrees C (12 hours), the temperature change in 150 microseconds is about 2.1x10 to 7 degree C. If it takes into consideration that the amount of pulse delay in the quartz fiber of nylon coating which forms the transmission line of a lightwave signal is maximum about 0.2ps/m/degree C (actual measurement), the amount of pulse delay produced when the temperature of the 100km whole transmission line changes with atmospheric temperature fluctuation will serve as 4.2x10-3ps among 150 microseconds. this -- resolution -- as well as the electric sampling of 20ps extent, since it is the value which can also disregard the lightwave signal light sampling of 1ps extent, the eye pattern by this approach can be evaluated as a synchronous eye pattern in false.

[0014]

in addition -- as the range of the offset frequency a -- for example

[Equation 9]

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k,\ q\text{は自然数})$$

It sets up so that it may become.
[0015]
Here, n/m and the semantics which k and q express are explained in full detail for the below-mentioned <example of a display of the eye pattern in the gestalt of each operation>.
Moreover, the input signal (data signal) in the data signal quality evaluation equipment of this invention may not be limited to the lightwave signal of the bit rate f0 (bit/s) which was mentioned above, but may be an electrical signal of a bit rate f0 (bit/s). What is necessary is to omit the photo-electric-translation means 11 and just to input the input electrical signal of a bit rate f0 into the electrical signal electrical-and-electric-equipment sampling means 12 directly with the gestalt of operation shown in drawing 1 in that case.
[0016]
Moreover, I hear that not making the repeat frequency f1 of a sampling clock follow in footsteps of the bit phase of a lightwave signal (or electrical signal) using a clock extract etc. generates the sampling signal of a frequency f1 (Hz) repeatedly independently of a data signal, and there is. "Independence" means that the tracking of the bit phase relation between a data signal and a sampling signal always is not carried out here.

[0017]
moreover, the reading appearance of two or more sampling data from the electrical-potential-difference maintenance means 14 by the electrical signal processing means 16 -- carrying out -- you may make it read two or more sampling data at once, and may make it read them one by one
[0018]
<The 2nd operation gestalt>
The 2nd operation gestalt of the data signal quality evaluation equipment of this invention is shown in drawing 2 . This depends on this invention according to claim 10. This operation gestalt is the case where the lightwave signal electrical-and-electric-equipment sampling means 22 is used, as a data signal sampling means. In this case, the data signal to input is a data signal of light, and the sampling clock generating means 23 is used as a sampling pulse train generating means. In this case, since the sampling signal (sampling lightwave signal) of light is acquired by the lightwave signal electrical-and-electric-equipment sampling means 22, in order to change this sampling signal into electric digital data and to hold it, after performing photo electric translation, the procedure of performing analog-to-digital conversion is required. Therefore, in drawing 2 , it has composition using the electrical-potential-difference maintenance means 14 with a analog-to-digital conversion function after the photo-electric-translation means 21. The same reference mark is attached to the same configuration as drawing 1 in drawing 2 . Actuation of this operation gestalt is explained below.
[0019]
The lightwave signal of a bit rate f0 (bit/s) results in the lightwave signal electrical-and-electric-equipment sampling means 22. On the other hand, repeat frequency f1(Hz) (f1=(n/m) f0+a or f1=(n/m) f0-a:n, and m are generated in the natural number, a is generated from the sampling clock generating means 23 in offset frequency), and a sampling clock results in this lightwave signal electrical-and-electric-equipment sampling means 22. Here, electric short pulse generating by the combination of a synthesized signal generator and a comb generator etc. can be used for the sampling clock generating means 23. As for the repeat frequency f1 of this sampling clock, it is desirable that it is the high speed of MHz-GHz extent here. Moreover, the band of this comb generator is extended to about 4 times of the bit rate f0 of a lightwave signal, and it is desirable to determine the pulse width of this electric short pulse as time amount width-of-face extent called for with the Fourier transform of the band of this comb generator. Moreover, electric amplifier can also be used for the preceding paragraph or the latter part of this comb generator if needed. Moreover, a baseband clipper can also be used for the latter part of this comb generator if needed.
[0020]
With this lightwave signal electrical-and-electric-equipment sampling means 22, this lightwave signal is sampled with this sampling clock, and the sampling lightwave signal of a bit rate f1 is acquired. The gate actuation by the electroabsorption modulator etc. can be used for this lightwave signal electrical-and-electric-equipment sampling means 22. The transparency band of the lightwave signal of this lightwave signal electrical-and-electric-equipment sampling means 22 is good in it being about lightwave signal bit rate f0 desirably here. Moreover, the sampling gate width of face of this lightwave signal electrical-and-

electric-equipment sampling means 22 has desirably good or less 1/4 extent of the time amount decided by the inverse number of the bit rate f0 of a lightwave signal. This sampling lightwave signal is changed into a sampling electrical signal by the photo-electric-translation means 21.
[0021]
With the electrical-potential-difference maintenance means 14, according to the trigger signal of the data taking-in initiation from the trigger signal generating means 15, analog-to-digital conversion (AD translation) of this sampling electrical signal is performed, and temporary storage maintenance actuation is performed. And this electrical-potential-difference maintenance means 14 holds two or more sampling data until the trigger signal of data taking-in termination is sent from this trigger signal generating means 15, and outputs it according to the trigger signal from the outside. Here, it can have electric buffer memory with the capacity for example, more than a kilobyte, and a high-speed AD translation circuit with the function of a MHz-GHz sampling etc. can be used. In this electrical-potential-difference maintenance means 14, if the trigger signal of data reading initiation is sent towards the electrical signal processing means 16 from the trigger signal generating means 15 after performing fixed time data taking in and holding two or more sampling data, according to the trigger signal of nucleus data reading initiation, this electrical signal processing means 16 will read two or more sampling data from this electrical-potential-difference maintenance means 14, and will evaluate a lightwave signal quality parameter in quest of a signal eye pattern from these sampling data.
[0022]
<The 3rd operation gestalt>
The 3rd operation gestalt of the data signal quality evaluation equipment of this invention is shown in drawing 3 . This depends on this invention according to claim 10. This operation gestalt is the case where the lightwave signal light sampling means 32 is used, as a data signal sampling means. In this case, the data signal to input is a data signal of light, and the sampling light pulse train generating means 33 is used as a sampling pulse train generating means. In this case, since the sampling signal (sampling lightwave signal) of light is acquired by the lightwave signal light sampling means 32, in order to change this sampling signal into electric digital data and to hold it, after performing photo electric translation, the procedure of performing analog-to-digital conversion is required. Therefore, in drawing 3 , it has composition using the electrical-potential-difference maintenance means 14 with a analog-to-digital conversion function after the photo-electric-translation means 21. The same reference mark is attached to the same configuration as what is shown in drawing 1 or drawing 2 in drawing 3 . Actuation of this operation gestalt is explained below.
[0023]
The lightwave signal of a bit rate f0 (bit/s) results in the lightwave signal light sampling means 32. On the other hand, repeat frequency f1(Hz) (f1=(n/m) f0+a or f1=(n/m) f0-a:n, and m are generated in the natural number, a is generated from the sampling light pulse train generating means 33 in offset frequency), and a sampling light pulse train results in this lightwave signal light sampling means 32. This sampling light pulse train has pulse width sufficiently narrower than the time amount decided by the inverse number of the bit rate f0 of a lightwave signal here. The laser diode of a gain switch mold, fiber ring laser, a mode locking laser diode, etc. can be used for this sampling light pulse train generating means 33. As for the repeat frequency f1 of this sampling light pulse train, it is desirable that it is the high speed of MHz-GHz extent here. Moreover, as for the pulse width of this sampling light pulse train, about [of the time amount decided by the inverse number of the bit rate f0 of ****** / 1/4 or less] is desirable.
[0024]
With this lightwave signal light sampling means 32, this lightwave signal is sampled in this sampling light pulse train, and a sampling lightwave signal is acquired. Here, the nonlinear optical effect between a lightwave signal and a sampling light pulse train can be used for the lightwave signal light sampling means 32, and nonlinear optics media, such as KTP (KTiOPO4), AANP (2-adamantylamino-5-nitropyridine), and PPLN (Periodically Poled Lithium Niobate), can be used for it. Moreover, as a nonlinear optical effect, SFG (sum cycle light generating), SHG (second harmonic generation), FWM (4 light-wave mixing), etc. can be used.
[0025]
This sampling lightwave signal is changed into a sampling electrical signal by the photo-electric-translation means 21. With the electrical-potential-difference maintenance means 14, according to the trigger signal of the data taking-in initiation from the trigger signal generating means 15, analog-to-digital conversion (AD

translation) of this sampling electrical signal is performed, and temporary storage maintenance actuation is performed. Two or more sampling data until the trigger signal of data taking-in termination is sent from this trigger signal generating means 15 are held. And it is outputted according to the trigger signal from the outside. Here, it can have electric buffer memory with the capacity for example, more than a kilobyte, and a high-speed AD translation circuit with the function of a MHz-GHz sampling etc. can be used. In this electrical-potential-difference maintenance means 14, if the trigger signal of data reading initiation is sent towards the electrical signal processing means 16 from the trigger signal generating means 15 after performing fixed time data taking in and holding two or more sampling data, according to the trigger signal of this data reading initiation, this electrical signal processing means 16 will read two or more sampling data from this electrical-potential-difference maintenance means 14, and will evaluate a lightwave signal quality parameter in quest of a signal eye pattern from these sampling data.

[0026]

<The 4th operation gestalt>

This operation gestalt describes the example of an assessment procedure in case the exact value of the signal bit rate f0 is not known. First, if it is SDH when the signal format is known for example, it will be thought that a signal bit rate is either of ... 39.81312 Gbit/s 9.95328 Gbit/s 2.48832 Gbit/s. However, a actual signal bit rate can consider that only df (Hz) has shifted to accuracy, for example, permits df=**200ppm in SDH. A gap of only the part as which it will not consider df to f1, either, if only df determines the repeat frequency of a sampling clock based on the common divisor of 2.48832 Gbit/s, 9.95328 Gbit/s, and 39.81312 Gbit/s etc., without taking df into consideration noting that the signal bit rate has shifted actually arises. The f1 that what is necessary is just to fill f1=(n/m) f0**a (for n and m to be the natural number), and (n/m) 2q/{k+(n/m) q} f0 <=a<(n/m)2q/{k+(n/m) q-1} f0 (for k to be the natural number) So that it may carry out the sweep of the value of f1 or ikj<=Nsamp and ikj<=kz/{2q(k-z)} (i, j, and Nsamp are the natural number) may be filled, when not filling Measurement of the open eye pattern is enabled by carrying out the sweep of the value of f1, the value of k, the value of n/m, the value of q, and any one or more **. In addition, the semantics which n/m, and k, q and z express is explained in full detail in <the example of a display of the eye pattern in the gestalt of each operation> mentioned later. And the approach of carrying out the sweep of these parameters can be applied not only when a signal format shows a signal bit rate to some extent, but when a signal bit rate is not known at all. However, the demand to the adjustable width of face of f1 becomes large in that case.

The conditions which enable eye pattern measurement without the sweep of f1,

f1 >=(2, f0, Nsamp, and|df|) 1/2

By coming out, being, for example, in the case of f0=9.95328 Gbit/s, df=200ppm, and Nsamp=250, becoming f1>=1GHz order, and making a sampling rate into a high speed, even when a signal bit rate cannot be known to accuracy, eye pattern measurement is attained.

[0027]

<The example of quality evaluation by each operation gestalt>

With reference to drawing 4 thru/or drawing 8 , the example of quality evaluation by the 1st of this invention thru/or the 4th operation gestalt is explained. The typical example of a synchronous eye pattern and the example of an assessment parameter are shown.

[0028]

Drawing 4 is the example of the eye pattern of an NRZ signal (Non-Return-to-Zero signal). The amplitude histogram when setting up the time window of dt focusing on the time amount from which eye opening of the direction on the strength serves as max is shown, and the averages mu1 and mu0 and standard deviation sigma1 and sigma0 are evaluated about a mark and each distribution of a tooth space.

[0029]

moreover

Q=|mu1-mu0|/sigma1+sigma0

Q value come out of and calculated can also be made into an assessment parameter. Here, |mu1-mu0| expresses the absolute value of the difference of the averages mu1 and mu0.

[0030]

From Q value,

BER=erfc(Q)

A ******** bit error rate can be estimated. Here, BER expresses a bit error rate (Bit Error Rate), and erfc

expresses an error complementary function.
[0031]
Drawing 5 is the example of the eye pattern of RZ signal (Return to zero signal). The method of assessment of the averages mu1 and mu0, standard deviation sigma1 and sigma0, and Q value is the same as that of the case of NRZ mentioned above.
[0032]
Drawing 6 is the example of the eye pattern of an NRZ signal. The amplitude histogram when setting up the cross point of an eye pattern for the time window of dt as a core is shown, and the averages mu1 and mu0 and mucross are evaluated about a mark, distribution of a tooth space, and the frequency distribution near a cross point, respectively.
[0033]
here -- for example
Rcross=|mu cross-mu 0|/|mu1-mu0|
The gap of the amplitude reinforcement of a ** cross point is shown, and it becomes the parameter by which the effect of the pulse breadth by wavelength dispersion etc. is evaluated.
[0034]
Drawing 7 is the example of the eye pattern of an NRZ signal. The time histogram of the part surrounded by the time amount width of face dt and the width of face dI on the strength is shown, and standard deviation sigmat is evaluated. sigmat becomes the parameter by which the effect of a jitter is evaluated.
[0035]
Drawing 8 is the example of the eye pattern of RZ signal. Drawing of a left part shows the amplitude histogram when setting up the time window of dta focusing on the time amount from which eye opening of the direction on the strength serves as max, and is evaluating the averages mu1 and mu0 about a mark and each distribution of a tooth space. Upside drawing shows the time histogram of the part surrounded by the width of face dI on the strength and the time amount width of face dt of |mu1-mu0|/2 centering on a value, and is evaluating the difference TFWHM of standard deviation sigmat and the average. sigmat becomes the parameter by which the effect of a jitter is evaluated. TFWHM shows the full width at half maximum of RZ pulse, and serves as a parameter by which the pulse breadth by wavelength dispersion etc. is evaluated.
[0036]
In addition, assessment of degradation according to PMD (polarization mode dispersion) by setting the window of the time amount width of face dt and the frequency width of face dI as arbitration etc. is possible.
[0037]
<The example of a display of the eye pattern in the gestalt of each operation>
About a display, it can display on a display as it is at the order which sampled two or more sampling data, for example. In this case, no points can necessarily be arranged in time series, but overwrite can be carried out from the place of time amount zero once again a certain period. An eye pattern can be displayed by repeating it about all sampling points.
[0038]
Hereafter, the period which carries out overwrite is explained. Here, it is a, when the bit rate of a data signal is expressed with f0 (bit/s) and the repeat frequency f1 of a sampling (Hz) is expressed with f1=(n/m) f0+a or f1=(n/m) f0-a (the natural number and a are an offset frequency for n and m),
[Equation 10]

$$\frac{\left(\frac{n}{m}\right)^2 q}{k+\left(\frac{n}{m}\right)q} f_0 \leqq a < \frac{\left(\frac{n}{m}\right)^2 q}{k-1+\left(\frac{n}{m}\right)q} f_0 \qquad (k,\ q\text{は自然数})$$

The case where ****** is filled is explained.

It is a value related to the ratio of f0 and f1, for example, n/m is 1/100, and n/m is f0 here. When it is 10 (Gbit/s), f1 is set to about 100 (MHz), and a sampling point expresses that it is the sampling frequency which is extent obtained one point to about 100 bits of a data signal. Moreover, k is a value related to the period which carries out overwrite, and means carrying out overwrite k sampling point numbers at a time. Moreover, q is a value showing a part for what bit of a data signal is reproduced, when k sampling points are arranged in time series. Below, the example of a plot of the points P1-P8 corresponding to each sampling data is explained with reference to drawing 9 (a) - (d) about the case of f1=(n/m)-a as an example. Drawing 9 (a) is drawing (however drawing 9 (a) only the points P1-P5 graphic display) showing a data signal wave, and drawing 9 (b) - (d) is drawing showing the example of a plot. Moreover, each variable shall fill n/m=1, k= 4, and q= 1.
[0039]
In the above-mentioned case, the offset frequency a (=** (f1-f0)) serves as a value of the range of f(1/5) 0 <=a<(1/4) f0. That is, it is 1/4/f0 <=1/f1-1/f0<1/3/f0, and I hear that deltat (=1-/f1-1/f0) is set up smaller [it is larger than one fourth of one time slots which are the inverse number of f0, and] than one third, and there is. Points P1-P4 can reproduce the wave in 1 time slot by arranging in order (drawing 9 (b)).
[0040]
And in this example, a point P5 shall not be plotted following a point P4, but shall be returned and plotted to time amount zero. Here, there are two kinds of methods of superposition.
[0041]
(1) The 1st method of superposition is doubling the time amount location of a point P5 with the time amount location of a point P1, as shown in drawing 9 (c). If the time amount location of a point P5 is doubled with a point P1, the wave of the 2nd superposition will become the thing [wave / 1st] shifted somewhat in time. If it piles up like the 3rd time and the 4th time, since a gap will become large and will go little by little, when the count of superposition increases, the eye will close gradually. Information required to realize this superposition is only the value of n/m. Since a sampling clock can be set up locally, k is decided to be arbitration in the range of the natural number, and the period of overwrite is decided according to it. Although k is the natural number, if the wave is complicated, the larger one can tell a wave-like rendering that it is desirable.
[0042]
(2) The 2nd method of superposition is doubling the time amount location of a point P5 on the basis of the integral multiple of 1/f0, as shown in drawing 9 (d). If the time amount location of a point P5 is doubled on the basis of the integral multiple of 1/f0, the wave of the 2nd superposition will become what lapped with the 1st wave. Instead, it is necessary to get to know the absolute value of f0.
[0043]
Now, in the approach of (1), the gap when doubling the time amount location of a point P5 similarly to a point P1 is estimated. If it is a=(1/4) f0, since a point P5 is in agreement with a point P1 with the period of 1/f0, if it is that which carries out overwrite four points at a time (or overwrite is carried out by the multiple of 4), even if it will continue to infinity, a beautiful eye pattern is obtained. However, as shown in the formula which appoints the range of the above-mentioned a in this case, a has shifted from f(1/4) 0 for a while.
[0044]
If z is made into the real number which fills k-1<z<=k here,
[Equation 11]

$$a=\frac{\left(\frac{n}{m}\right)^{2}q}{z+\left(\frac{n}{m}\right)q}f_0$$

It comes out, it is, and since it is n/m=1 and q= 1 in now, it is set to a={1/(z+1)} f0 considering z as the real

number which fills 3< z<4. When it calculates using this, compared with the case of a=(1/4) f0, gap deltaT produced when piling up the wave is deltaT=(4-z)/(zf0). That is, generally, when the period of superposition is set to ik (i is i= 1 at the natural number and an example), it becomes deltaT=q(k-z) i/(zf0). conversely, if it says, it will pile up with 2 times and 3 times -- ** -- it will be said that it is written while it is alike and shifting in the direction of deltaT [every] time amount. Since an eye pattern will be thoroughly closed if accumulation of the gap becomes half [of one time slot of the inverse number of f0], it serves as an upper limit of a gap. It is ikj<=Nsamp, when the number of sampling points measured at once is set to Nsamp and the count of overwrite is set to j. Therefore, when accumulated of a gap is set to Sum [deltaT], Sum [deltaT] is,
[Equation 12]

$$Sum[\Delta T]=\frac{q(k-z)ij}{zf_0}$$

It becomes.
[0045]
Since that this becomes below one half of 1/f0 are the conditions which enable eye opening assessment,
[Equation 13]

$$\frac{(k-z)ijq}{zf_0}\leqq\frac{1}{2f_0}$$

It is got blocked.
[Equation 14]

$$ikj\leqq\frac{zk}{2q(k-z)}$$

In the range of the number of ******** sampling points, even if it uses a local clock, it will be said that eye opening can be evaluated.
[0046]
That is, the value of a
[Equation 15]

$$\frac{\left(\frac{n}{m}\right)^2 q}{z+\left(\frac{n}{m}\right)q}f_0 \qquad (z\text{は}k\text{-}1<z\leqq k\text{を満たす実数})$$

When coming out, and it is and the sampling data of a Nsamp individual are displayed in the direction of a time-axis with a dt=1/(zf0) time interval in order of measurement When data signal wave measurement and quality evaluation are performed in quest of a signal eye pattern by returning and laying a time amount location on top of every t=p/f0 (p being the natural number) 0, using the time amount location of the first sampling data as t= 0, and displaying sampling data, When the count of superposition is set to j (j is the

natural number), data signal quality evaluation can be performed by filling pkj<=Nsamp to the total number Nsamp of sampling data.

[0047]

If it is furthermore developed, it repeats performing data taking in of Nsamp and an eye pattern display as mentioned above j times, and after piling up j eye patterns on the basis of the maximum point of each eye opening, it can evaluate. If it carries out like this, the number of sampling points effectually used for assessment can be increased, and the indeterminacy of assessment can be reduced more.

[0048]

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the block diagram showing the configuration of the 1st of the gestalt of operation of this invention.
[Drawing 2] It is the block diagram showing the configuration of the 2nd of the gestalt of operation of this invention.
[Drawing 3] It is the block diagram showing the configuration of the 3rd of the gestalt of operation of this invention.
[Drawing 4] It is drawing for explaining an example of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 5] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 6] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 7] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 8] It is drawing for explaining other examples of the example of data signal quality evaluation by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 9] It is drawing for explaining the example of a data plot by the gestalt of operation shown in drawing 1 - drawing 3 .
[Drawing 10] It is the block diagram showing the configuration of the conventional example.
[Description of Notations]
11 Photo-Electric-Translation Means
12 Electrical Signal Electrical-and-Electric-Equipment Sampling Means
13 Sampling Clock Generating Means
14 Electrical-Potential-Difference Maintenance Means
15 Trigger Signal Generating Means
16 Electrical Signal Processing Means
21 Photo-Electric-Translation Means
22 Lightwave Signal Electrical-and-Electric-Equipment Sampling Means
23 Sampling Clock Generating Means
32 Lightwave Signal Light Sampling Means
33 Sampling Light Pulse Train Generating Means

[Translation done.]

* NOTICES *

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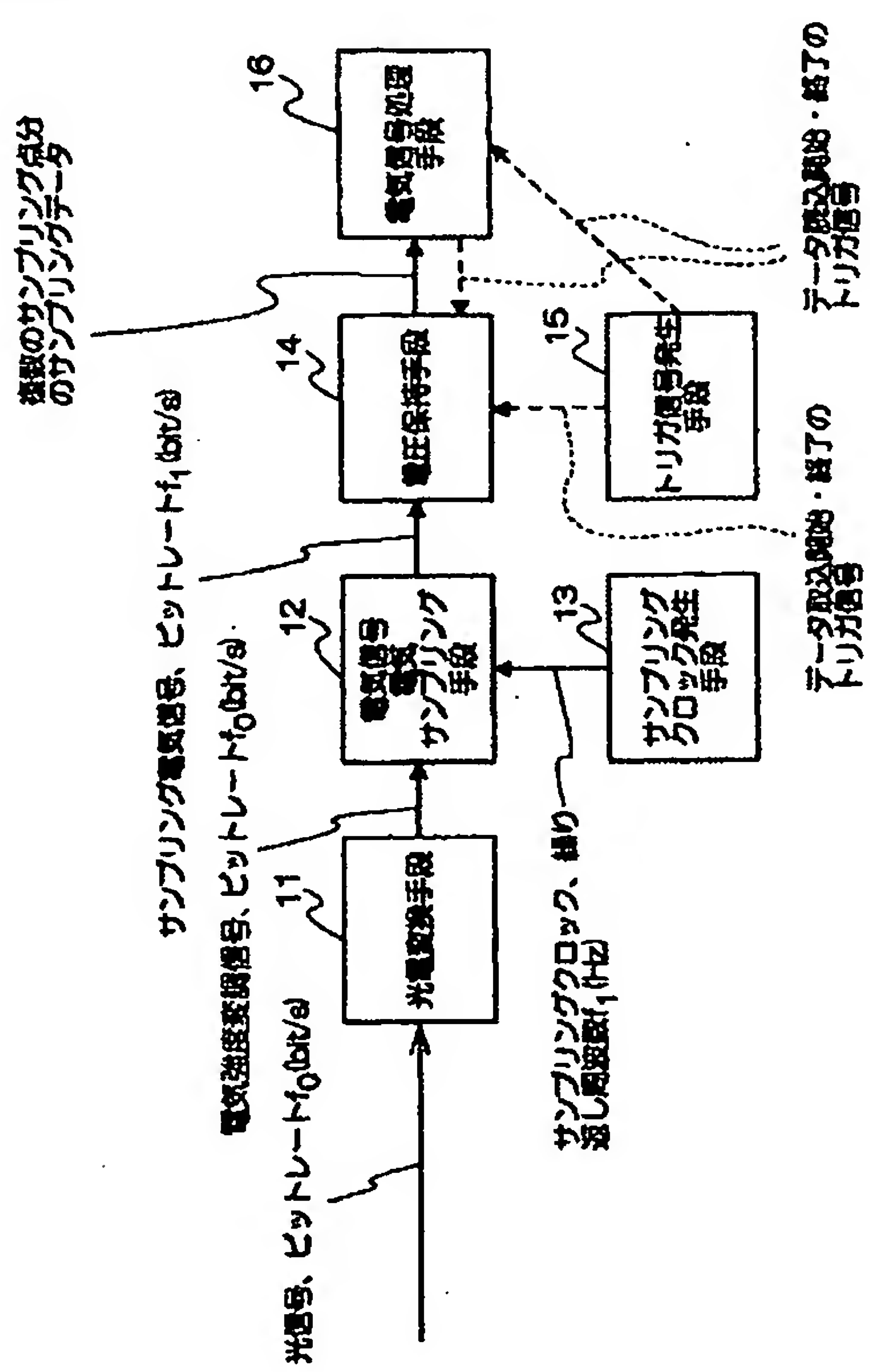
damages caused by the use of this translation.

1.This document has been translated by computer. So the translation may not reflect the original precisely.

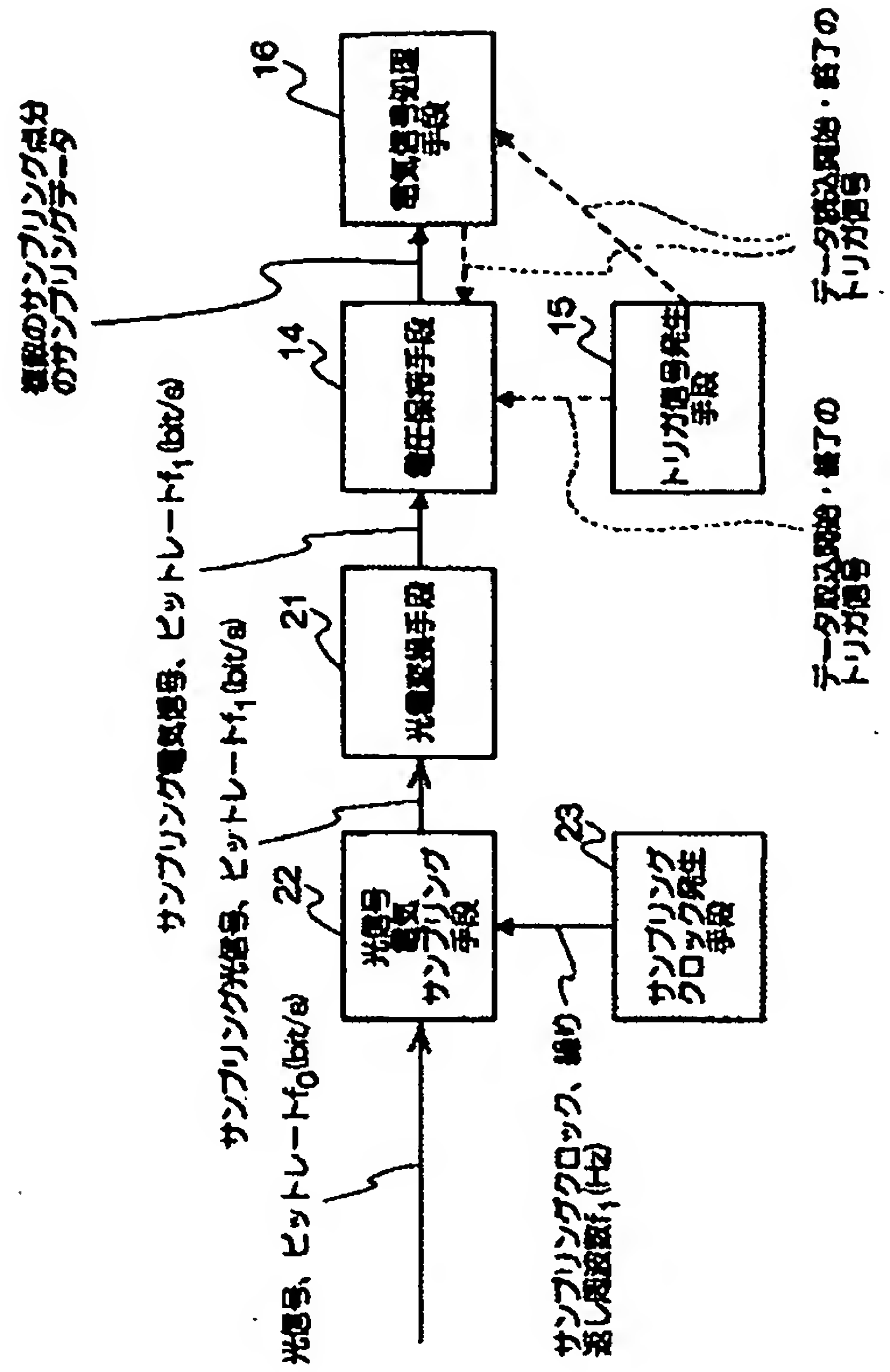
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

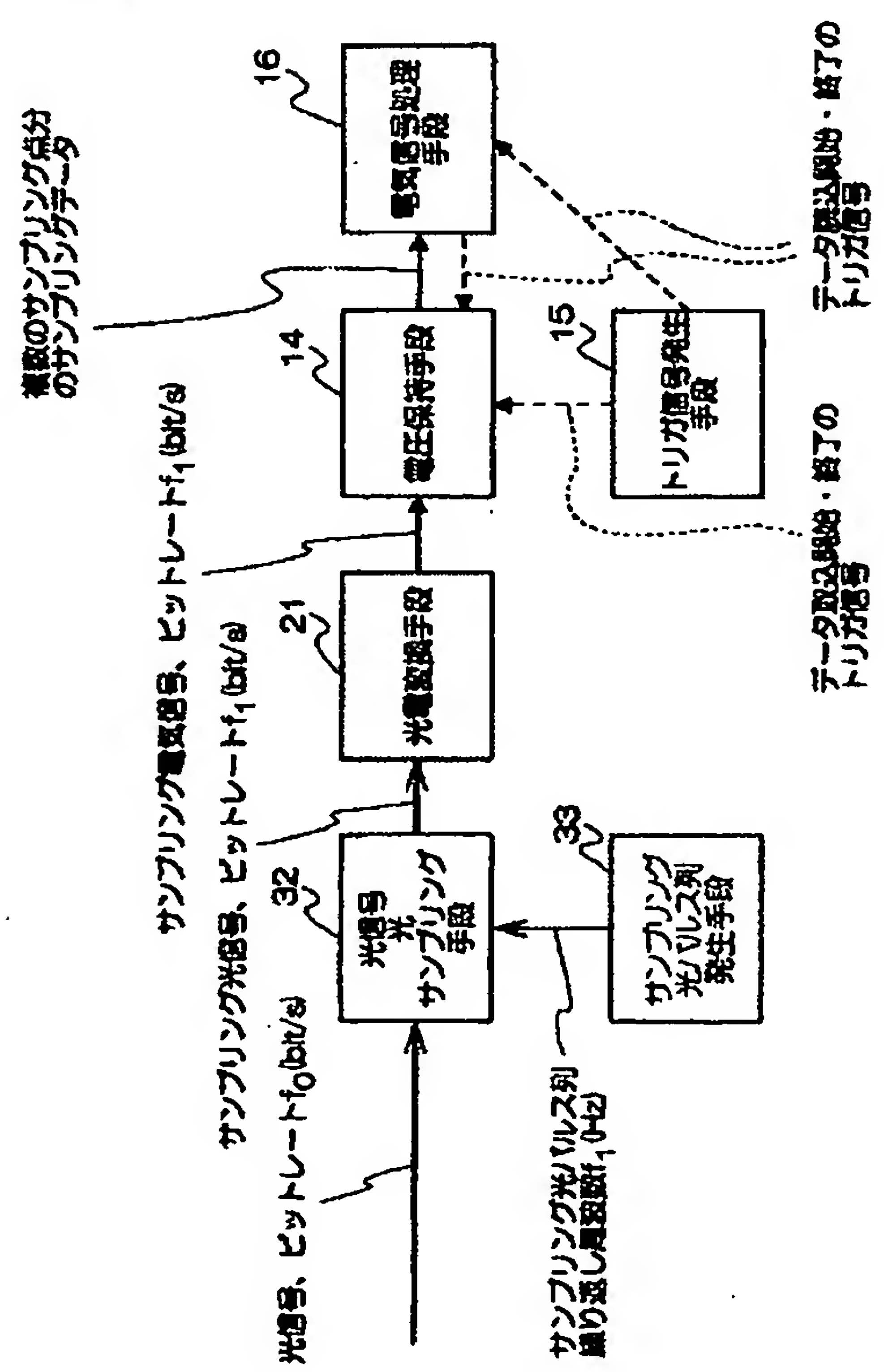
[Drawing 1]



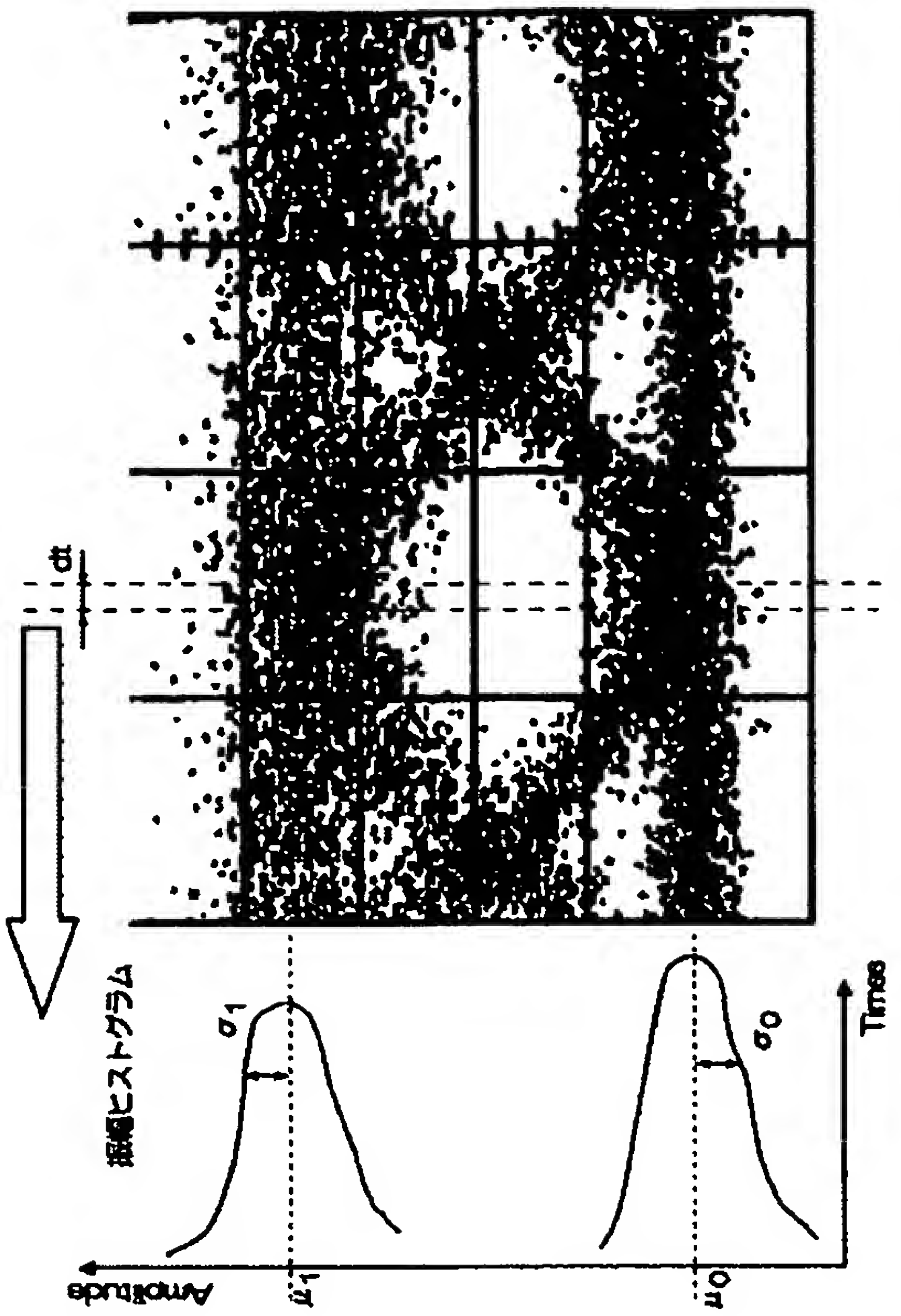
[Drawing 2]



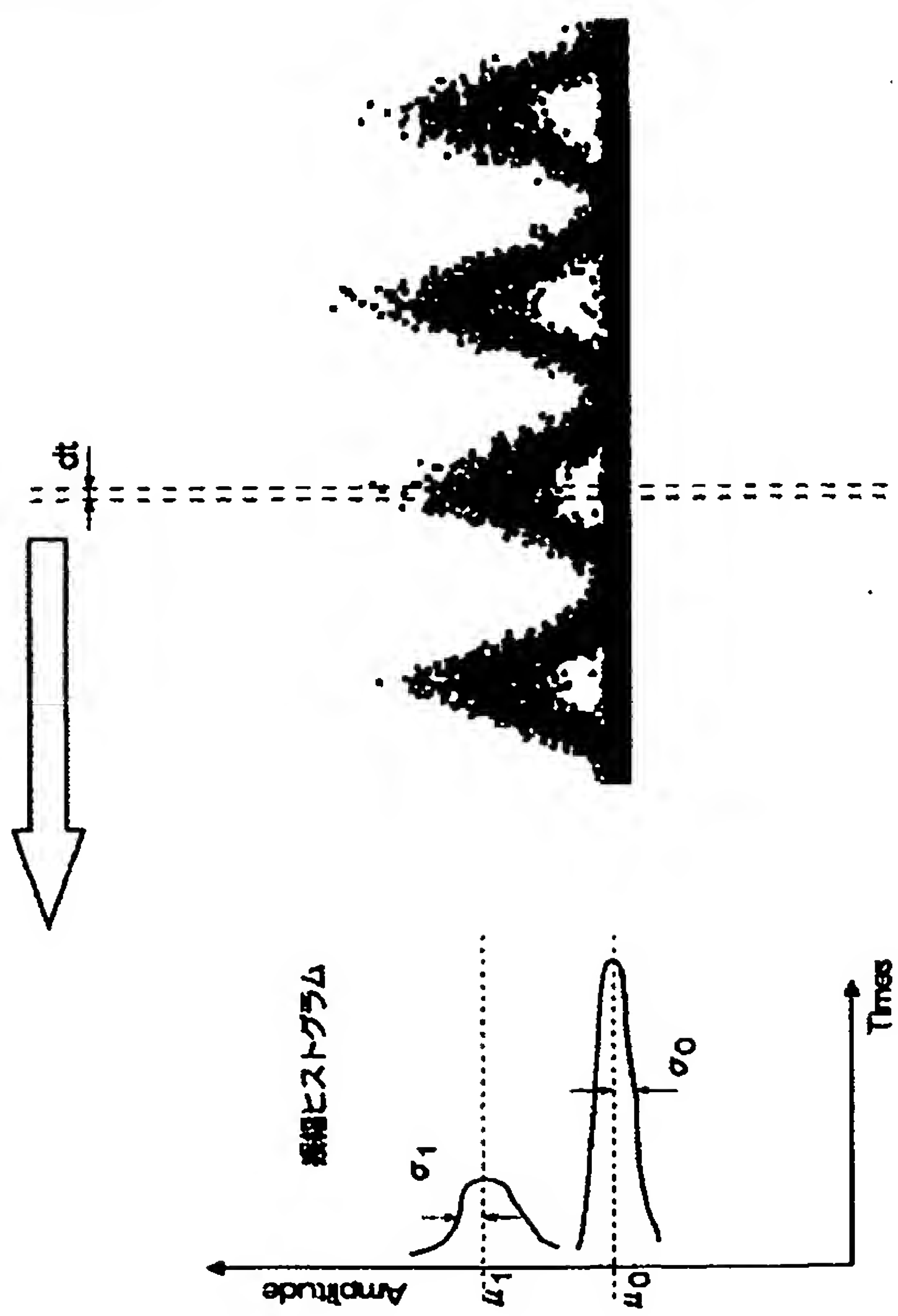
[Drawing 3]



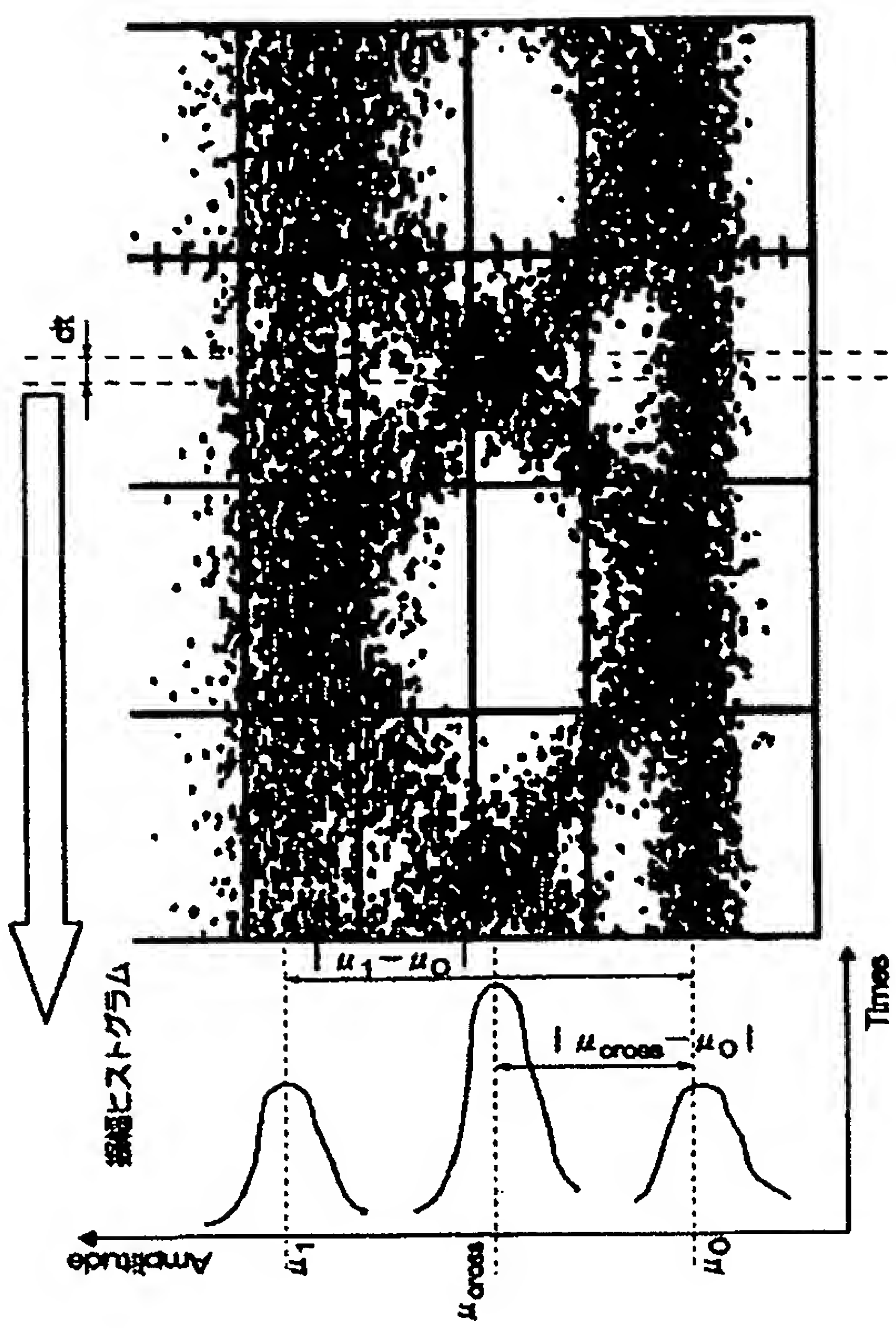
[Drawing 4]



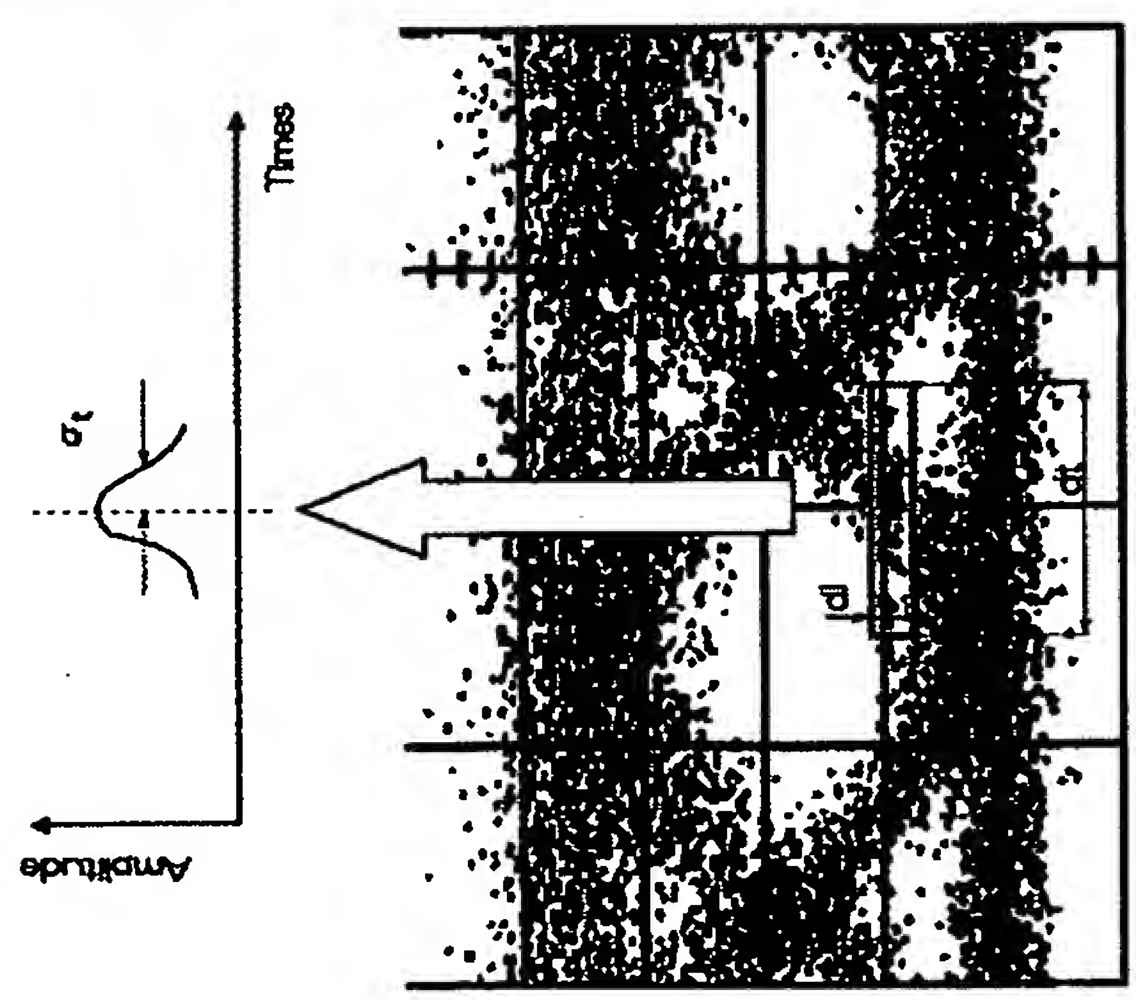
[Drawing 5]



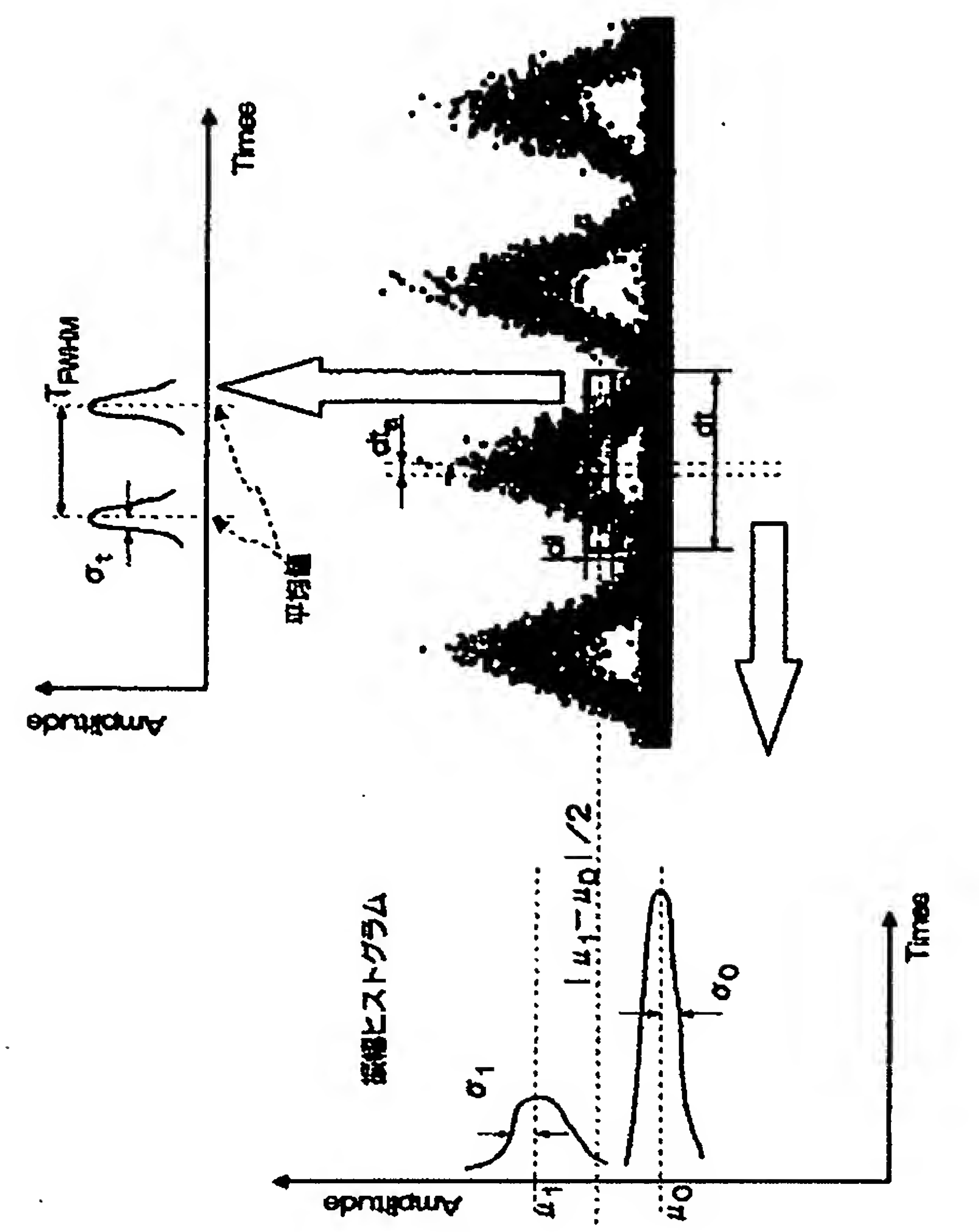
[Drawing 6]



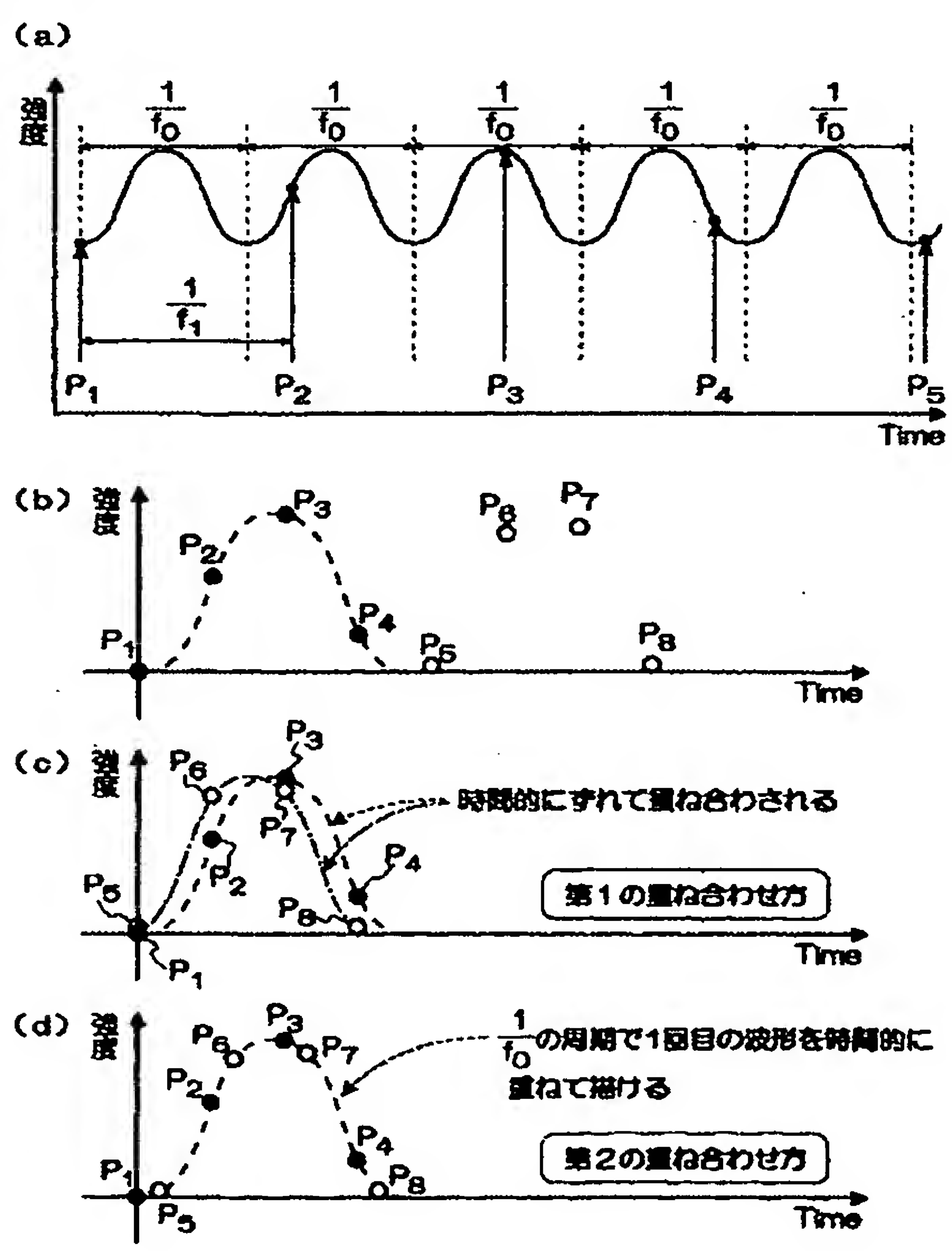
[Drawing 7]



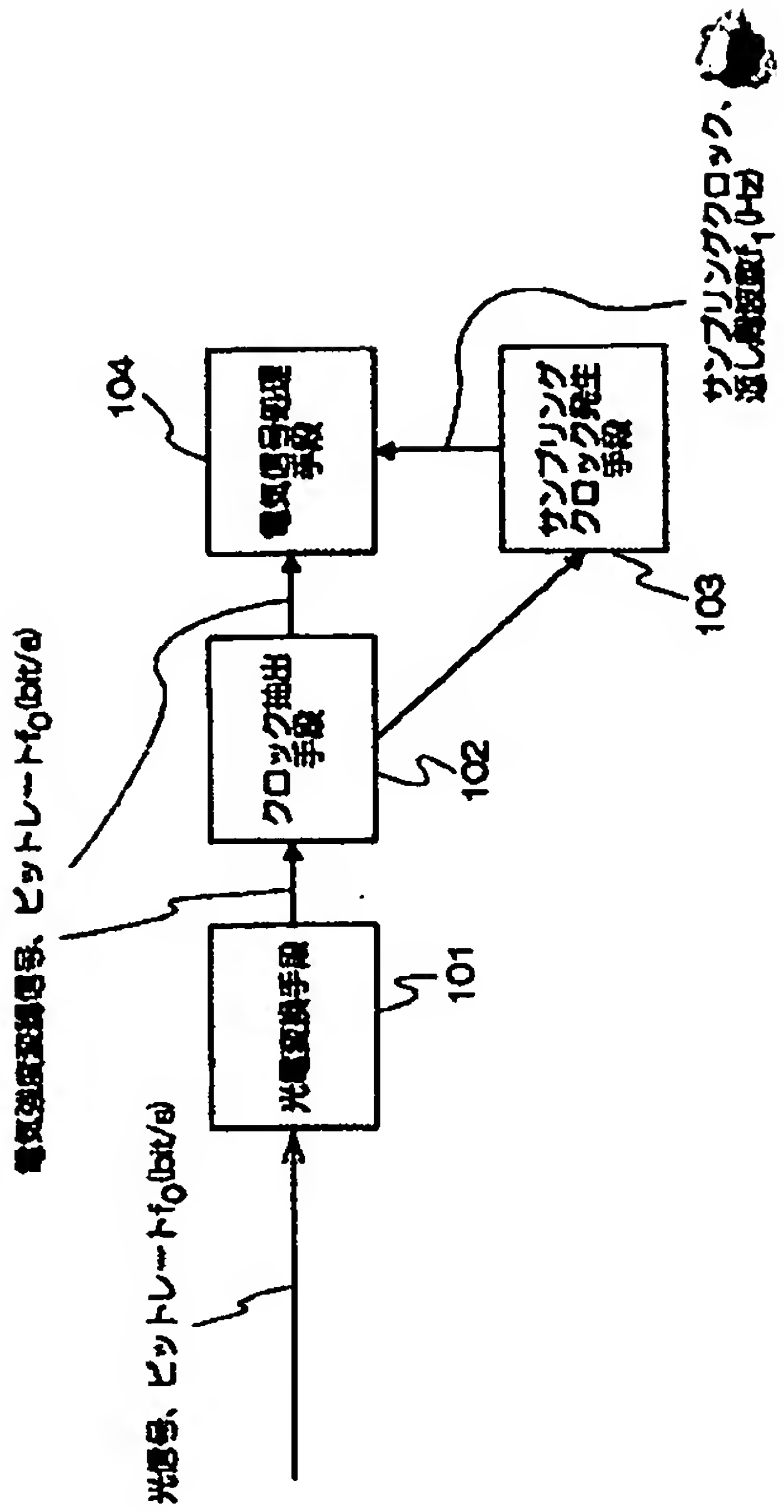
[Drawing 8]



[Drawing 9]



[Drawing 10]



[Translation done.]